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Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

JANUARY-FEBRUARY 1949

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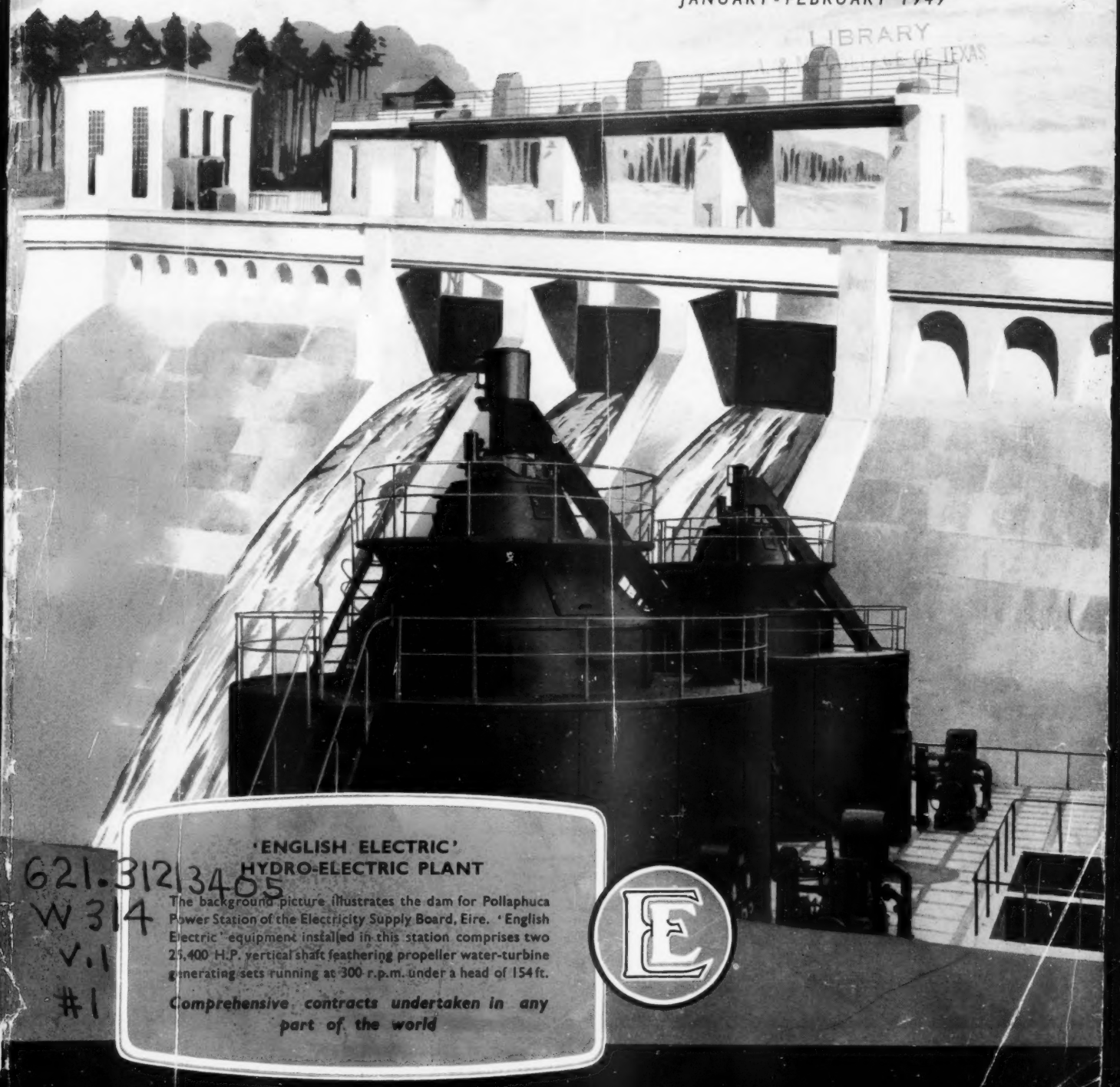

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'ENGLISH ELECTRIC' HYDRO-ELECTRIC PLANT

The background picture illustrates the dam for Pollaphuca Power Station of the Electricity Supply Board, Eire. 'English Electric' equipment installed in this station comprises two 25,400 H.P. vertical shaft feathering propeller water-turbine generating sets running at 300 r.p.m. under a head of 154 ft.

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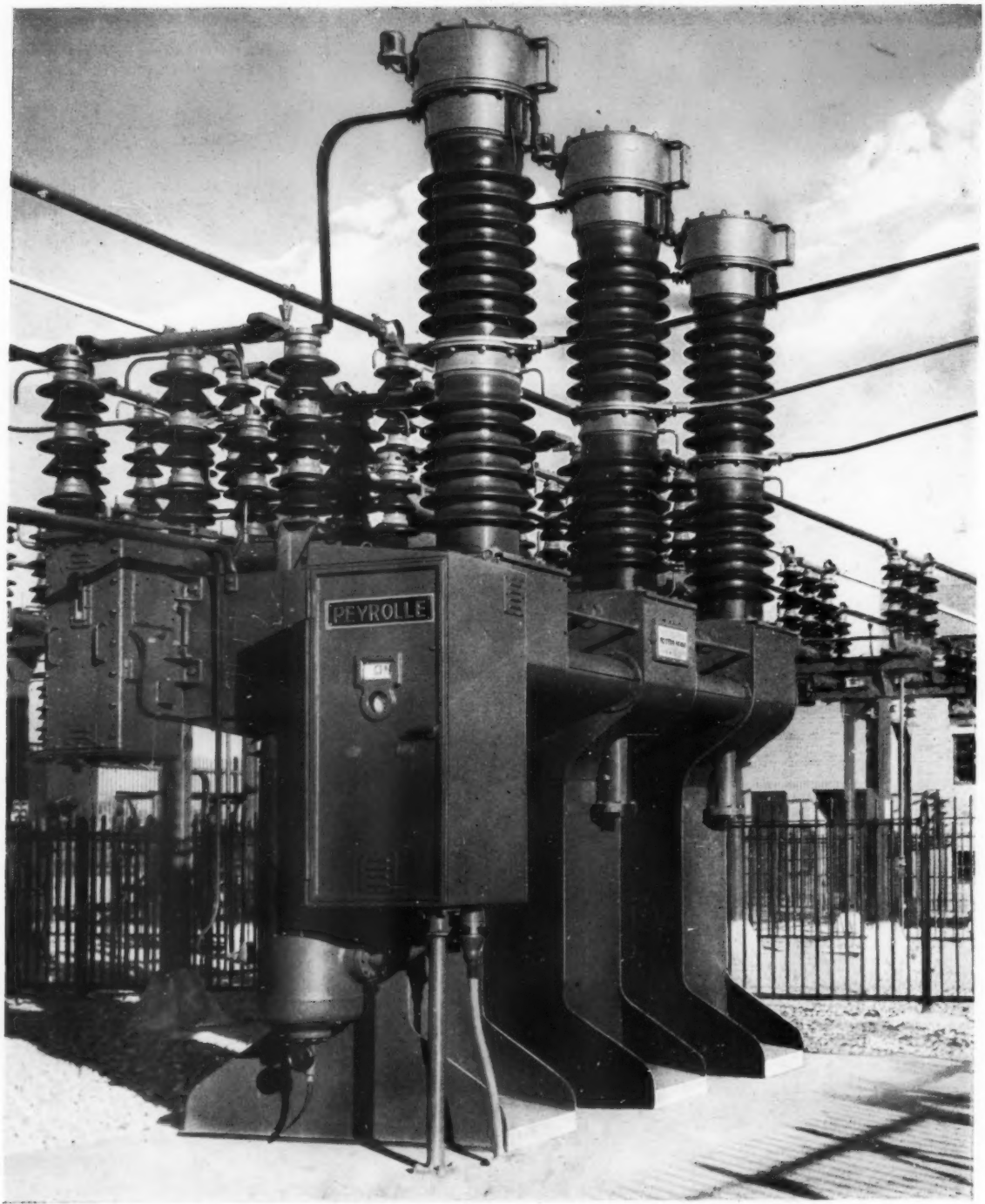
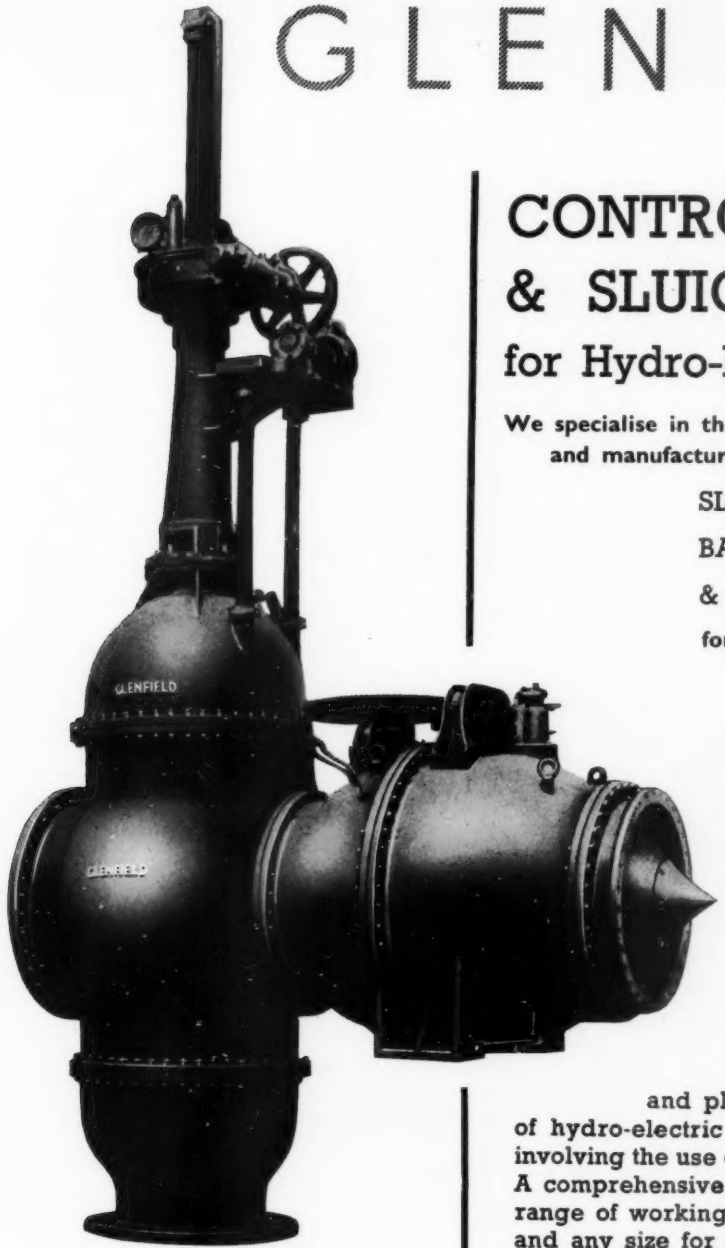


66-kV SMALL-OIL-VOLUME SWITCHGEAR, HERRINGTON BURN

REYROLLE
HEBBURN CO. DURHAM ENGLAND

GLENFIELD



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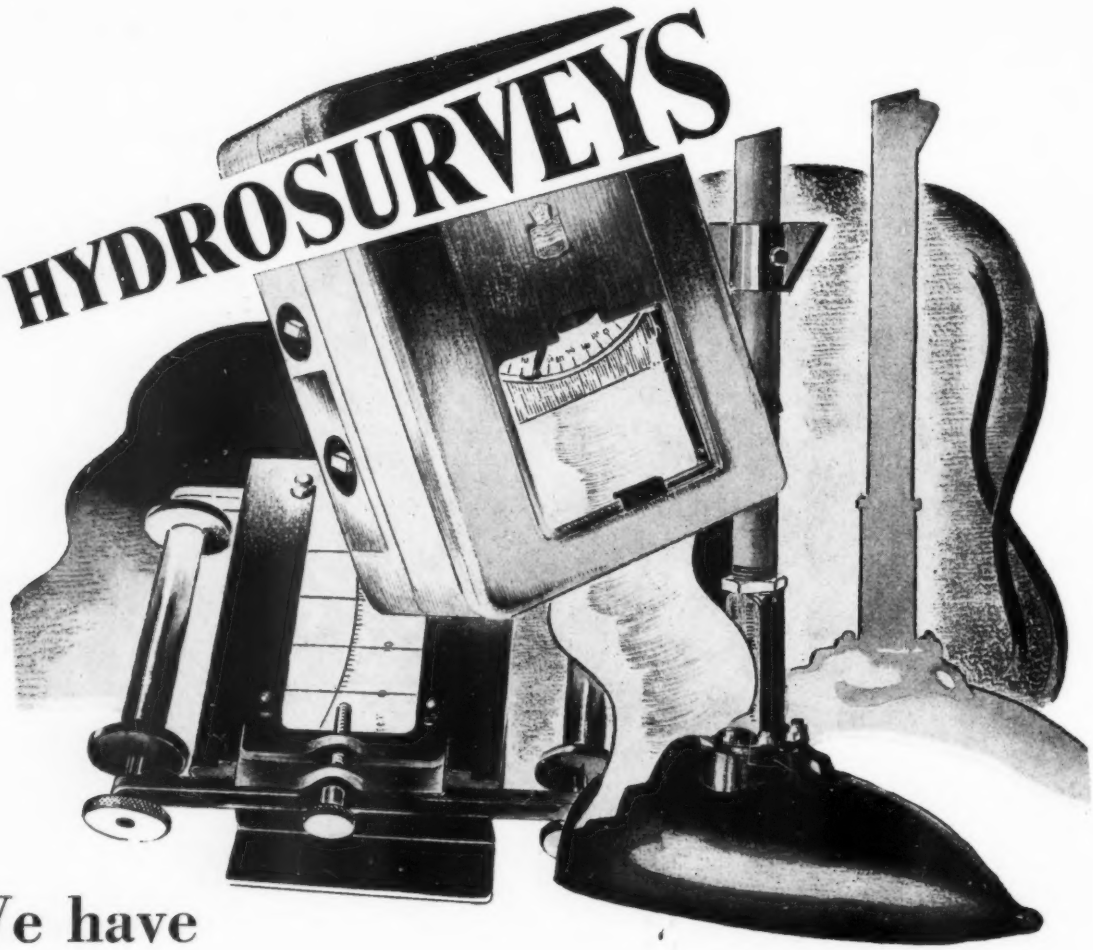

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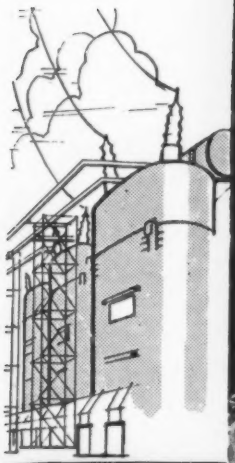

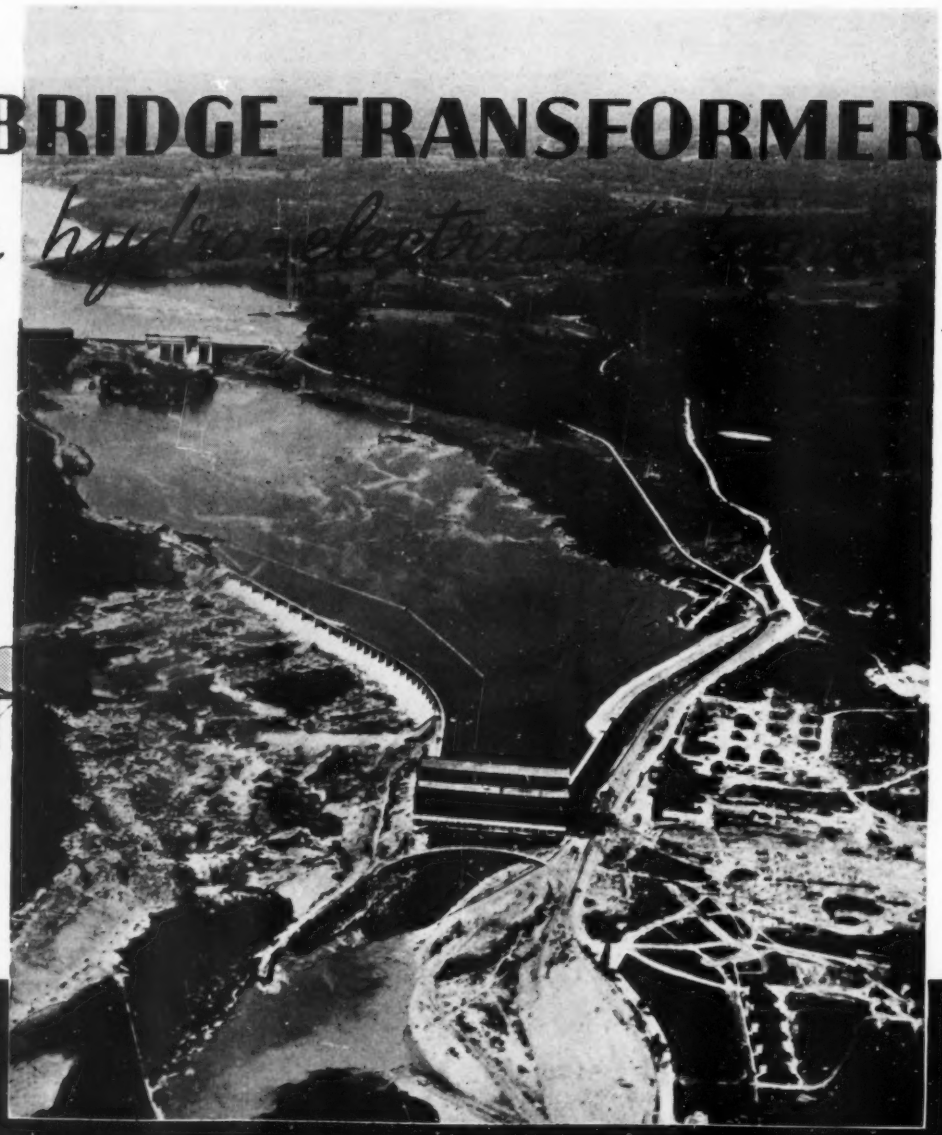

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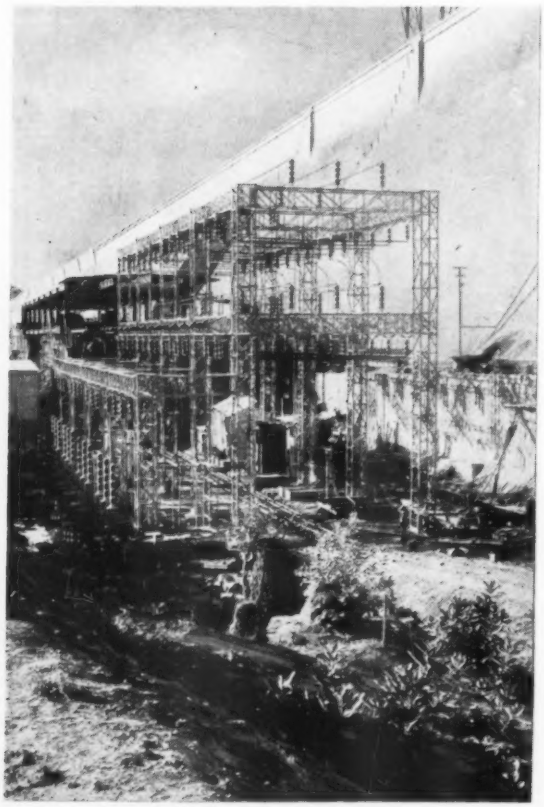
The Mettur Dam sub-station is one of many in South India equipped with posts type P.642 for 66KV and 110KV.



Photograph reproduced by courtesy of the main contractors, Messrs. A.E.I. (India) Ltd.

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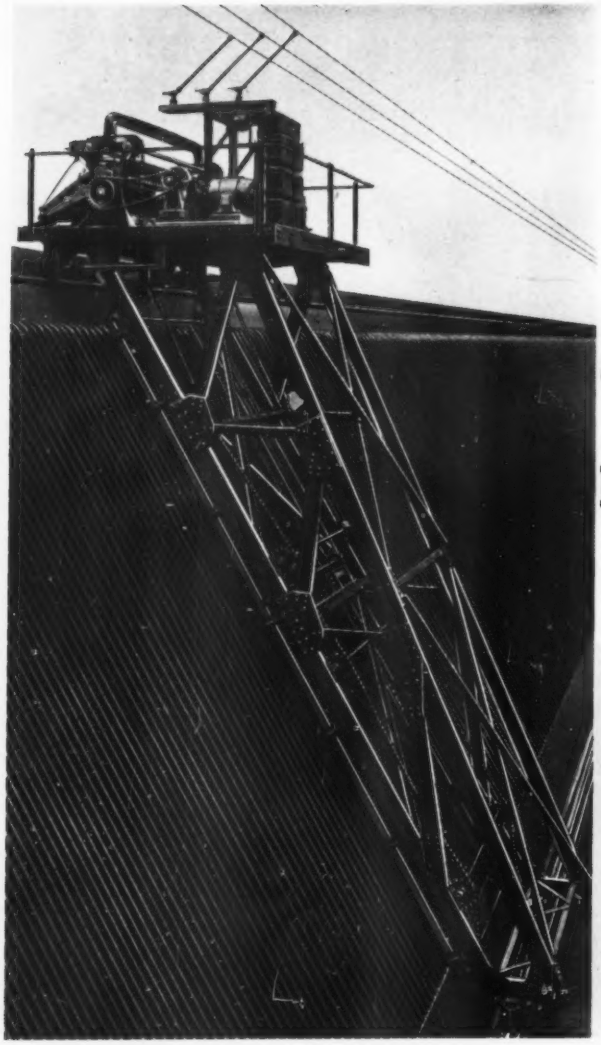

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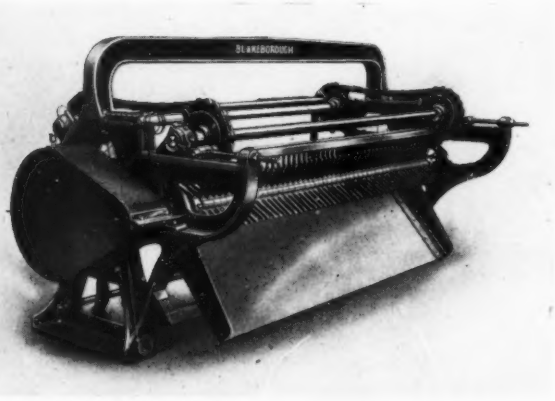
FOR INTAKE SCREENS



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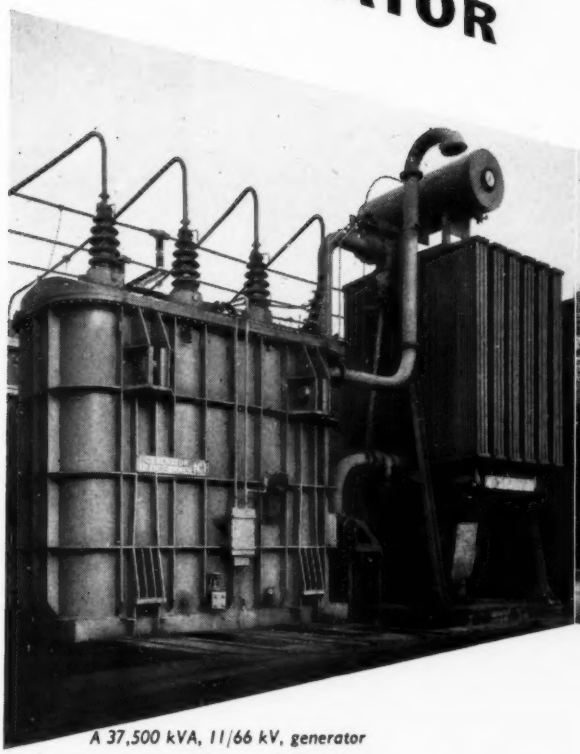
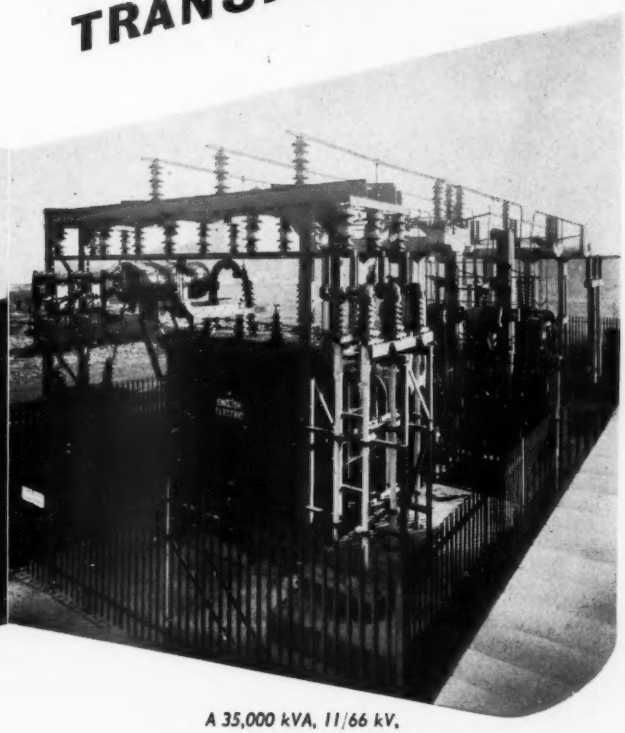


A 37,500 kVA, 11/66 kV, generator transformer at a power station in South Wales



A 35,000 kVA, 11/66 kV, generator transformer at a Yorkshire power station

Vital links in the chain transmitting and distributing electric power from generating stations to industry, " English Electric " transformers have built into them the fruits of long experience supported at every stage in their design and production by the resources of extensive and modernly equipped research laboratories including impulse voltage testing plant simulating the severest service conditions.

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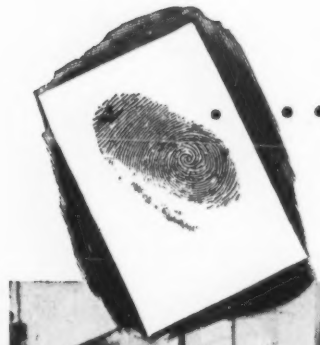

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View of Henderson Cableway during construction of Claerwen Dam. Courtesy of Birmingham Corporation Waterworks.

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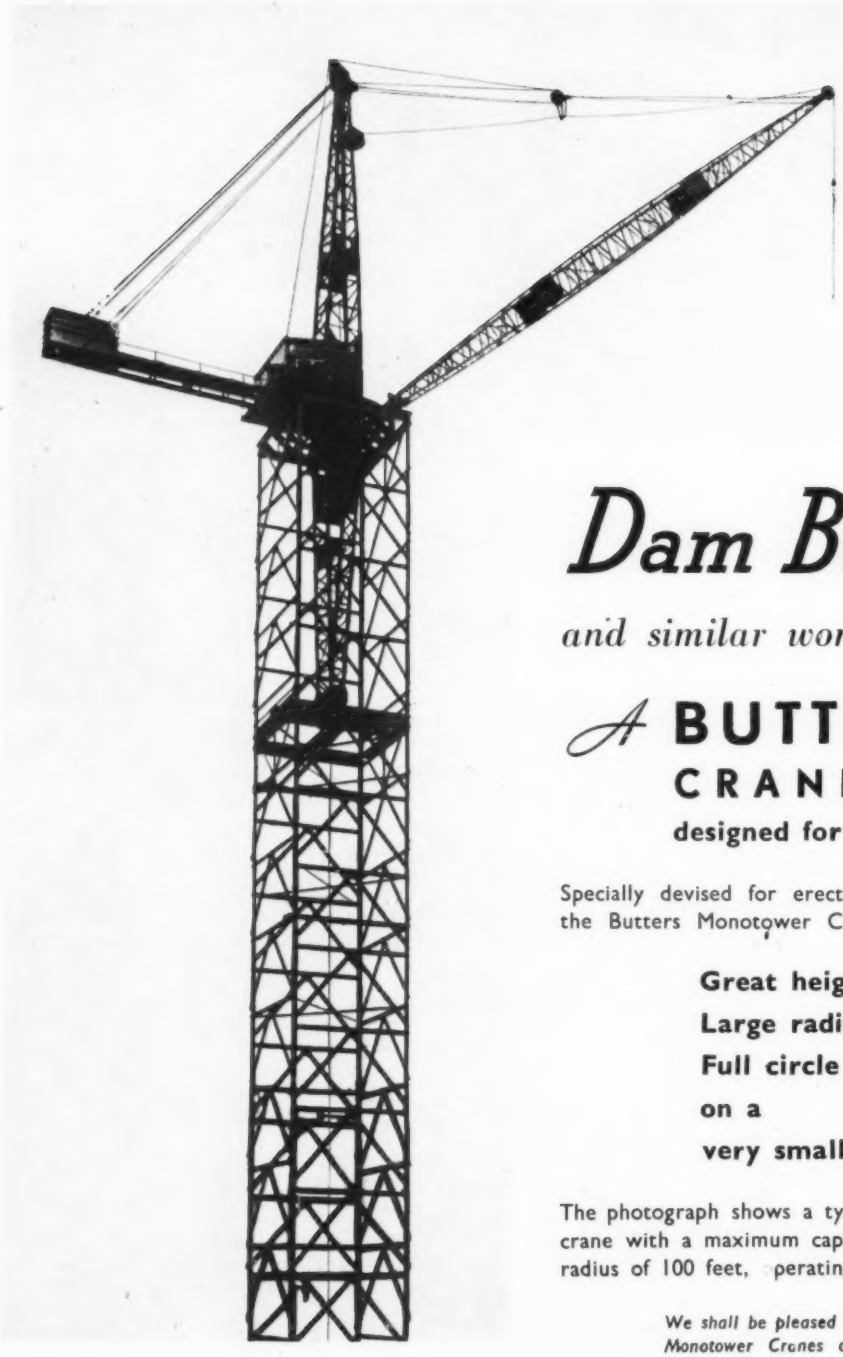

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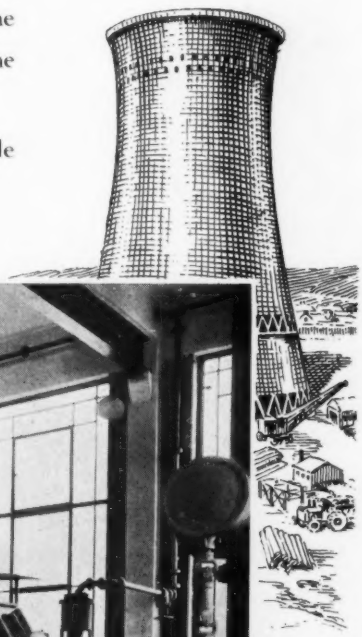
GILKES TURBINES

AT NEW POWER STATION, BOLTON

The photograph of the Back o' th' Bank Power Station, Bolton, illustrates a 280 BHP Gilkes Francis Turbine on 45ft. head (in foreground) and a 637 BHP Gilkes Francis Turbine on 102 ft. head (on left).

The Turbines work on returned water from the cooling tower, recovering a proportion of the energy expended in pumping water to the top of the tower. The base of the cooling tower is at a higher elevation than the power station, due to the lie of the land.

Turbines are direct coupled to English Electric motors driving Drysdale pumps which lift cooling water to the top of the tower.



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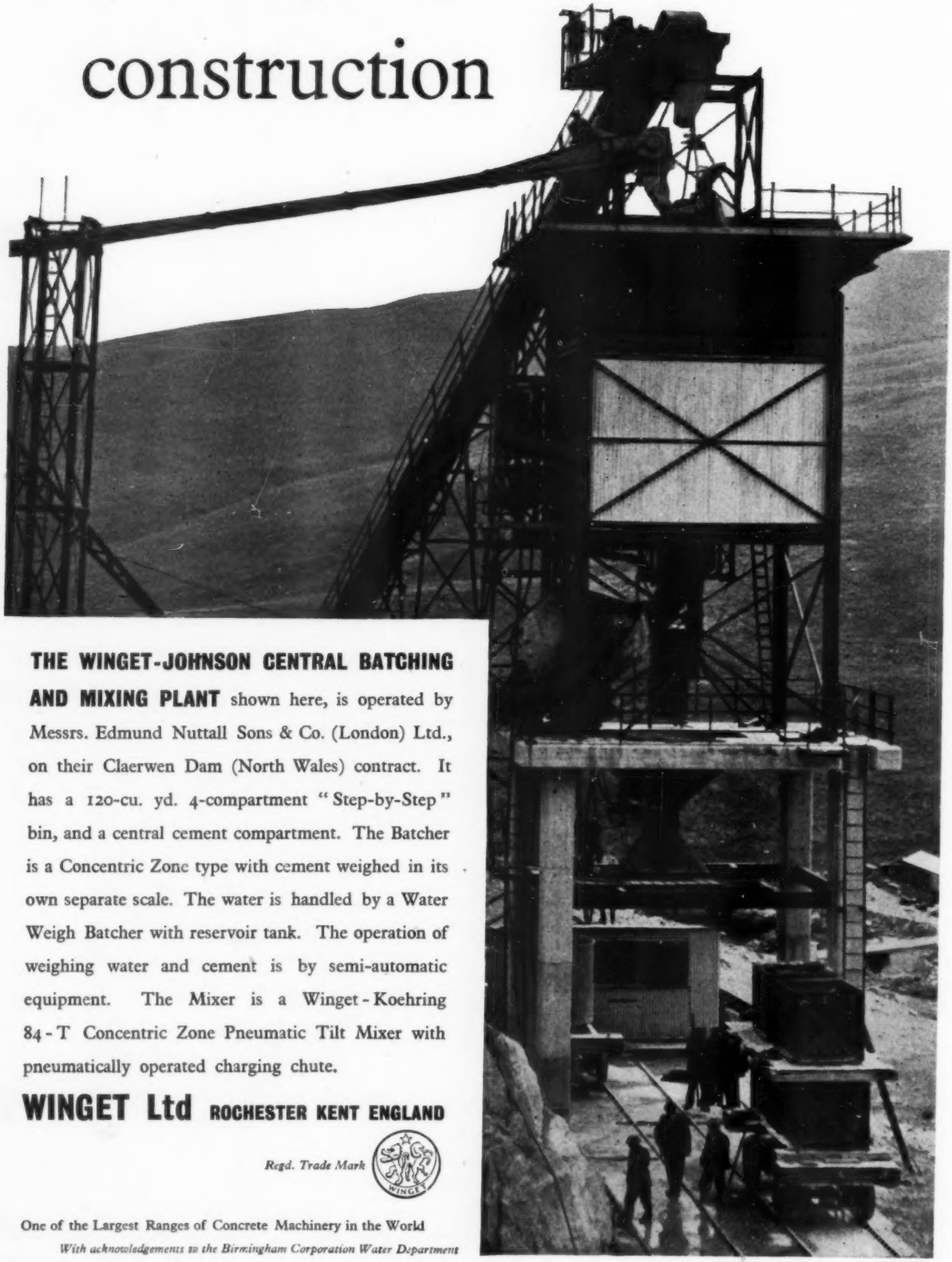
GILBERT GILKES & GORDON LTD · *Kendal · England*

'Phone : Kendal 28

GII

A Winget plant on dam construction



THE WINGET-JOHNSON CENTRAL BATCHING AND MIXING PLANT shown here, is operated by Messrs. Edmund Nuttall Sons & Co. (London) Ltd., on their Claerwen Dam (North Wales) contract. It has a 120-cu. yd. 4-compartment "Step-by-Step" bin, and a central cement compartment. The Batcher is a Concentric Zone type with cement weighed in its own separate scale. The water is handled by a Water Weigh Batcher with reservoir tank. The operation of weighing water and cement is by semi-automatic equipment. The Mixer is a Winget-Koehring 84-T Concentric Zone Pneumatic Tilt Mixer with pneumatically operated charging chute.

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With acknowledgements to the Birmingham Corporation Water Department

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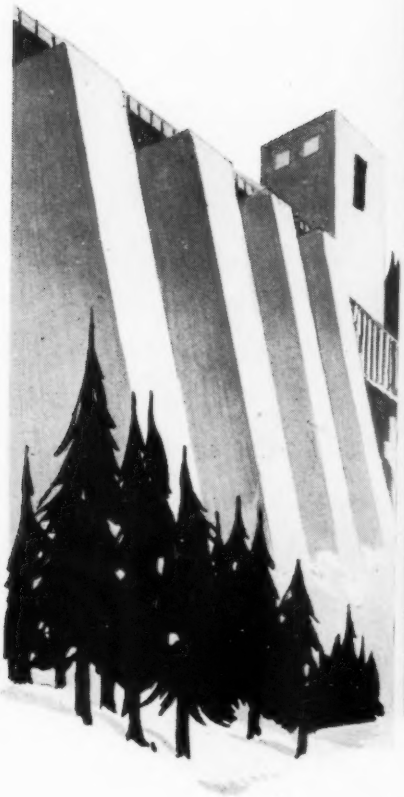

The illustration shows a Rock Drill RH-655W operated in conjunction with a pnematic pusher and a drill steel with tungsten carbide insert

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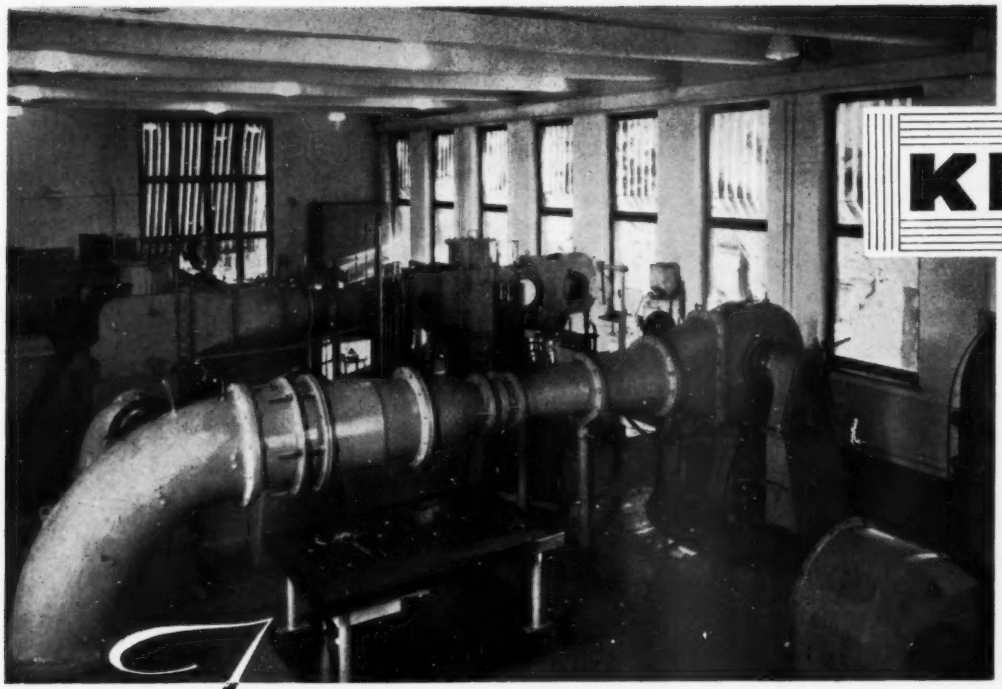

KMW

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For many years continuous research and experimental work have been carried out in the laboratories and testing station at our Kristinehamn Works in the development of FRANCIS, KAPLAN and PELTON turbines. In 1942 a new laboratory building was erected to accommodate all earlier testing equipment for turbines and pumps in addition to all that used for testing models of variable pitch propellers (KaMeWa Propellers) for ships.

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3. Cavitation characteristics of Francis and Kaplan turbines.
4. Pelton turbines.
5. Cavitation characteristics of ships' propellers.

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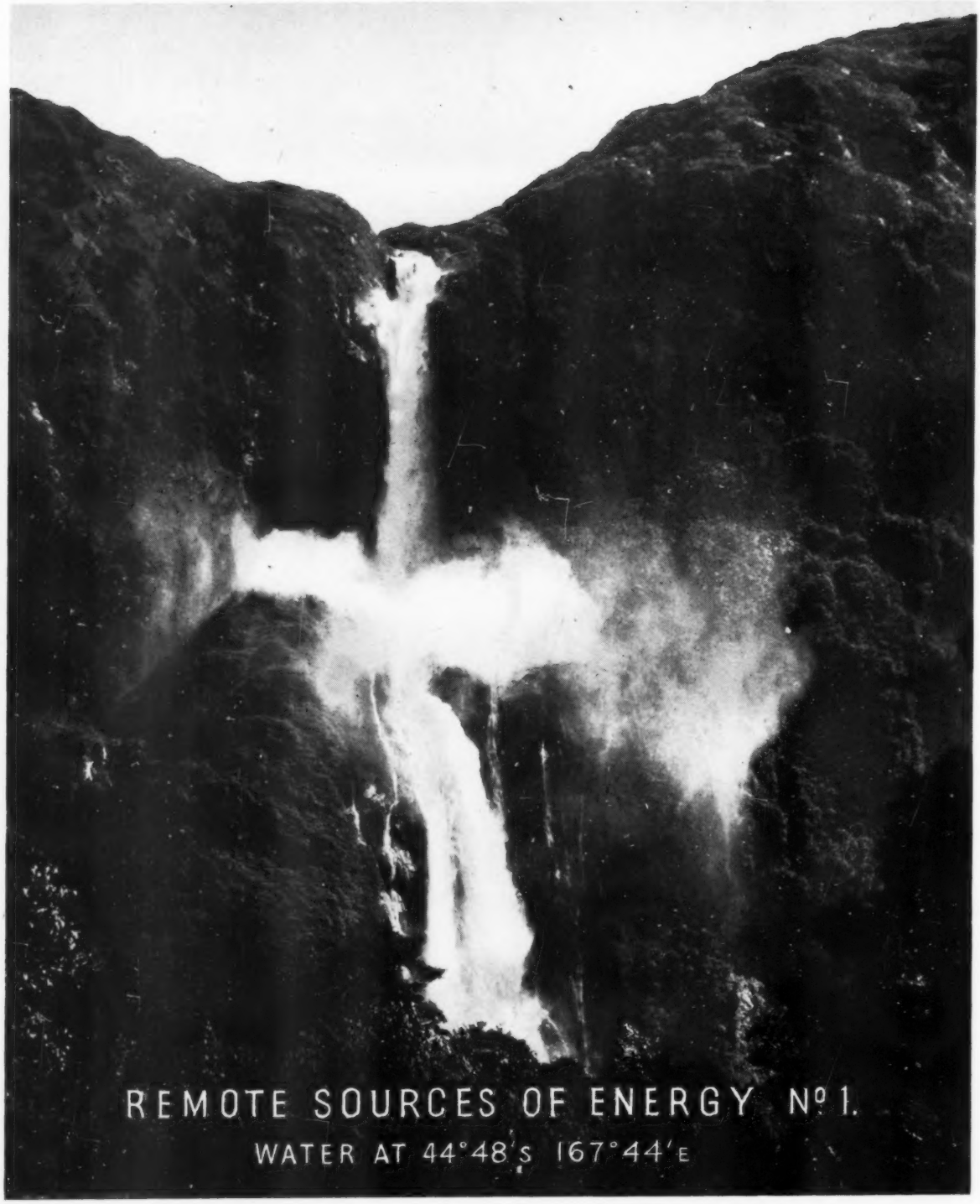
The excellent results attained in output and efficiency due to research and experimental work are one of the reasons why K.M.W. have reached the prominent position they now enjoy amongst the leading builders of water turbines in the world.

AKTIEBOLAGET KARLSTADS MEKANISKA WERKSTAD

KARLSTAD . SWEDEN



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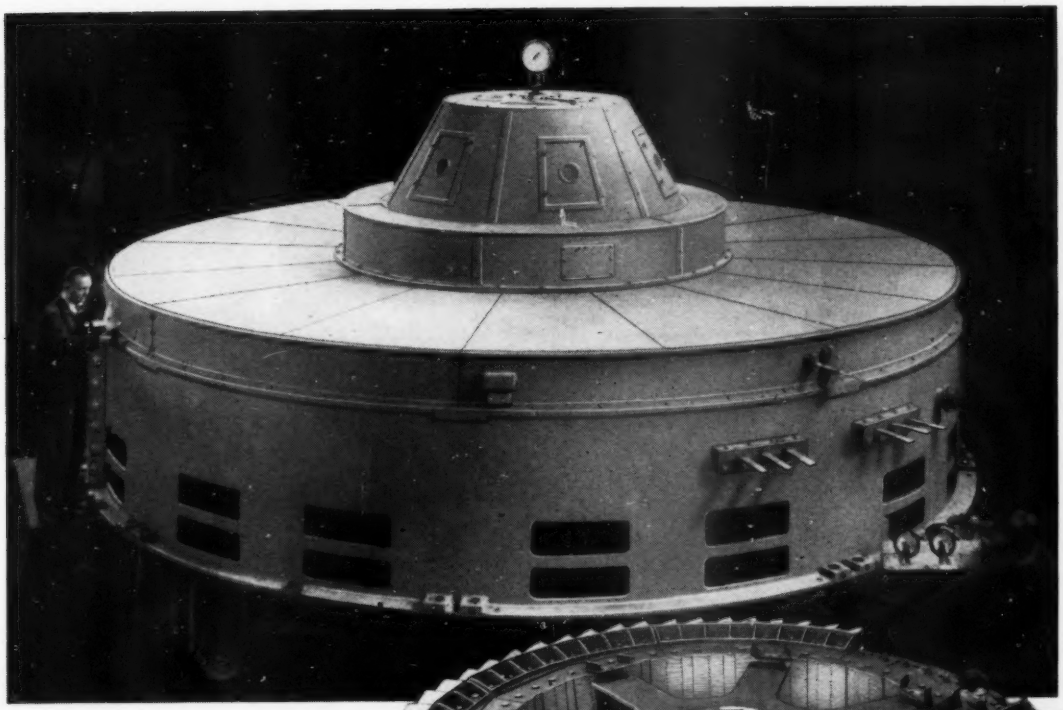
Hydro-electric Equipment



18,889 kVA, 214 r.p.m., 11,000 volt, 50-cycle three-phase water-wheel driven alternator (umbrella type) for the Clunie Power Station, of the North of Scotland Hydro-electric Board.

Rotor in course of construction in BTH works.

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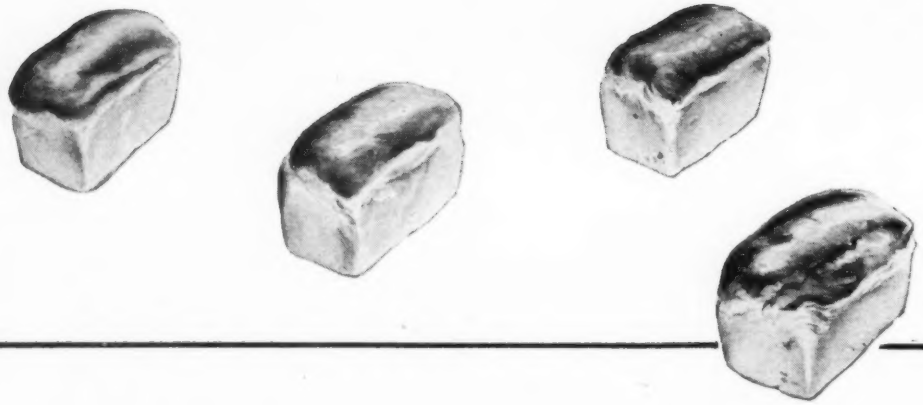
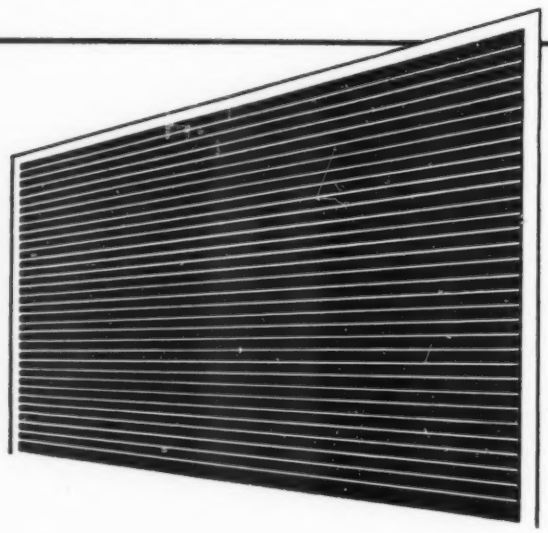


bread and shutter



are as naturally associated as bread and butter. For bread must arrive fresh. Must, therefore, arrive as quickly as possible. So up-to-date bakeries throughout the world are fixing, instead of doors, the Brady Roller Shutter . . . in every conceivable opening—for works' entrances—between departments—on delivery vans. A Brady Roller Shutter helps, instead of hinders, the smooth flow of goods. *Your* goods, too. An enquiry receives a prompt response—that's the first part of the Brady Service which continues throughout our association with you.

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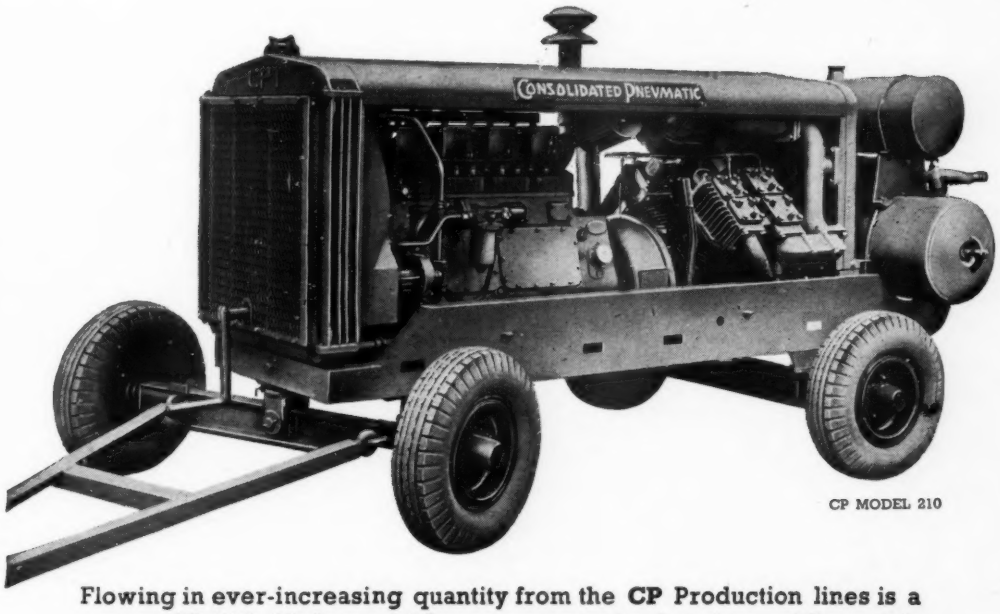

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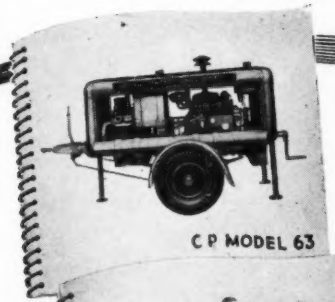

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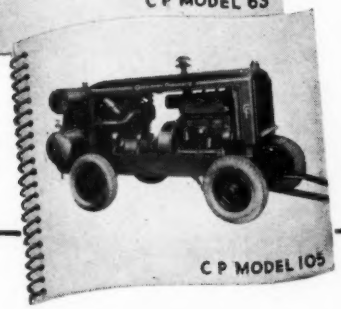

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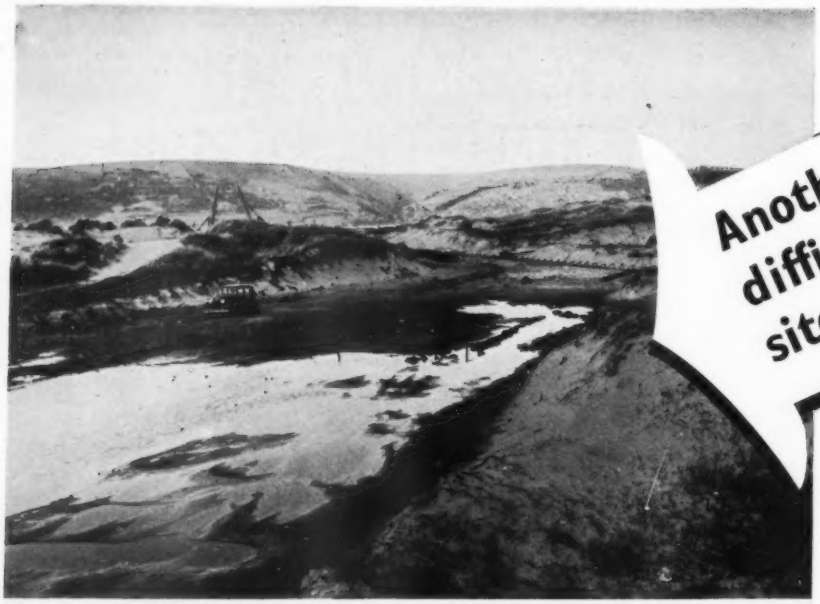

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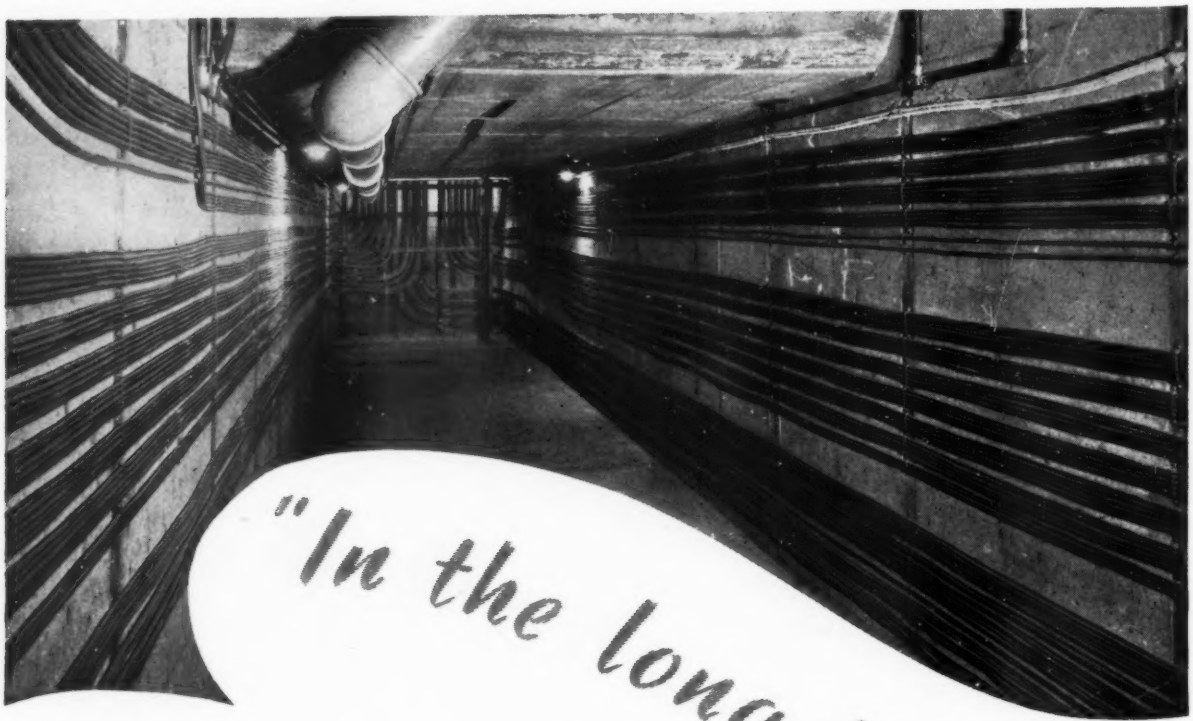

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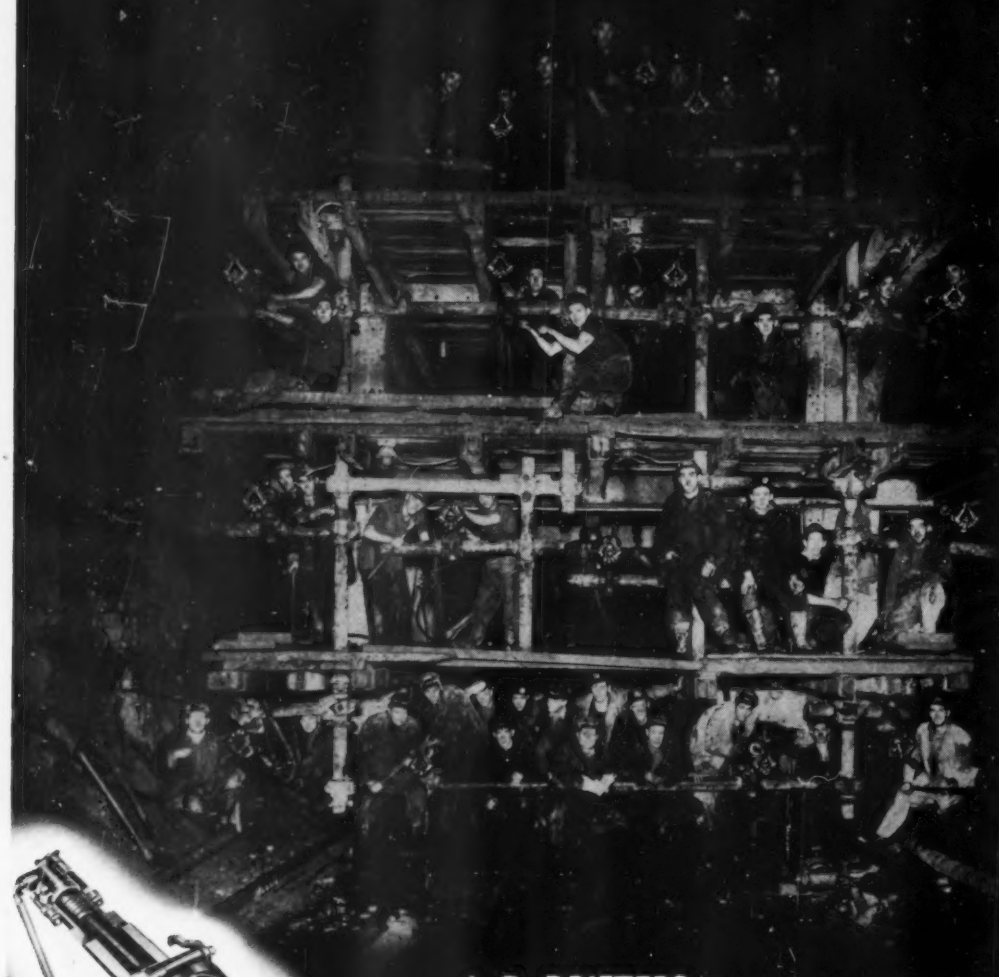

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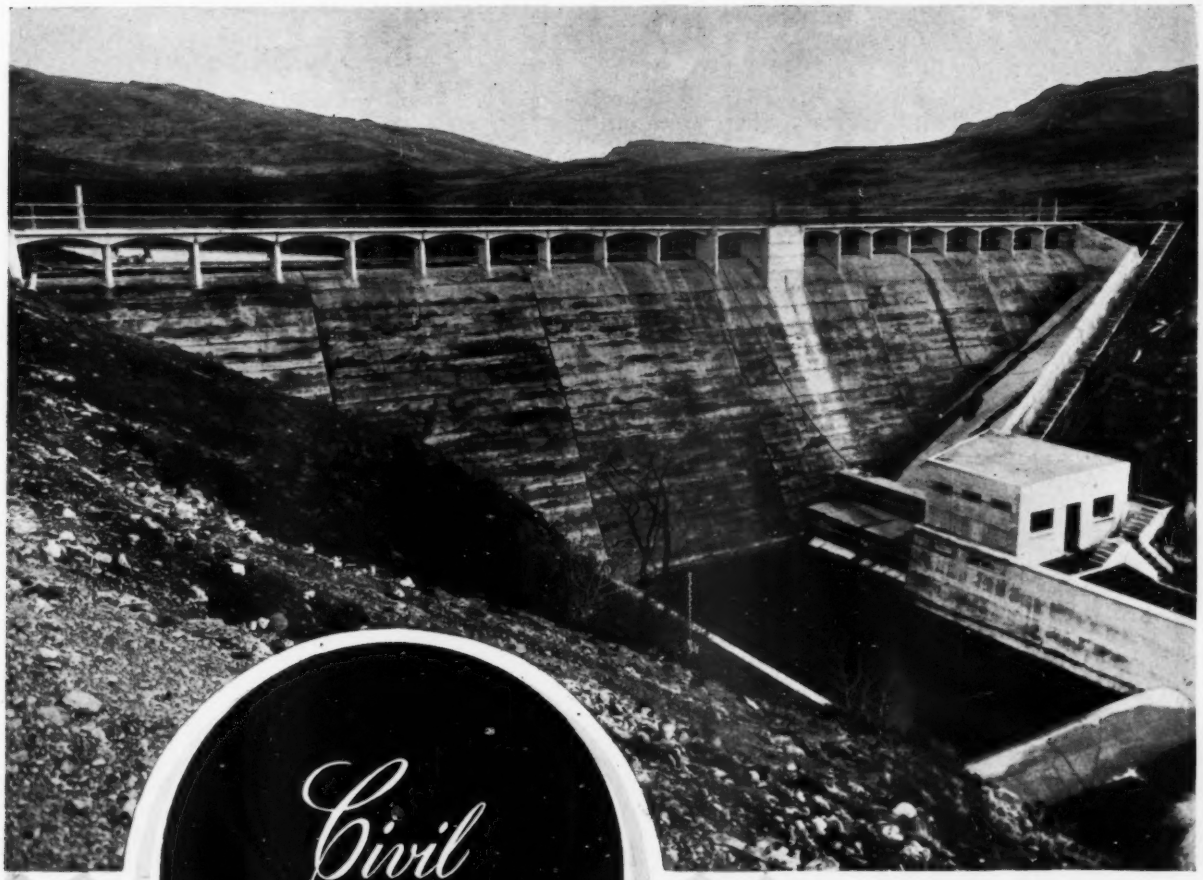

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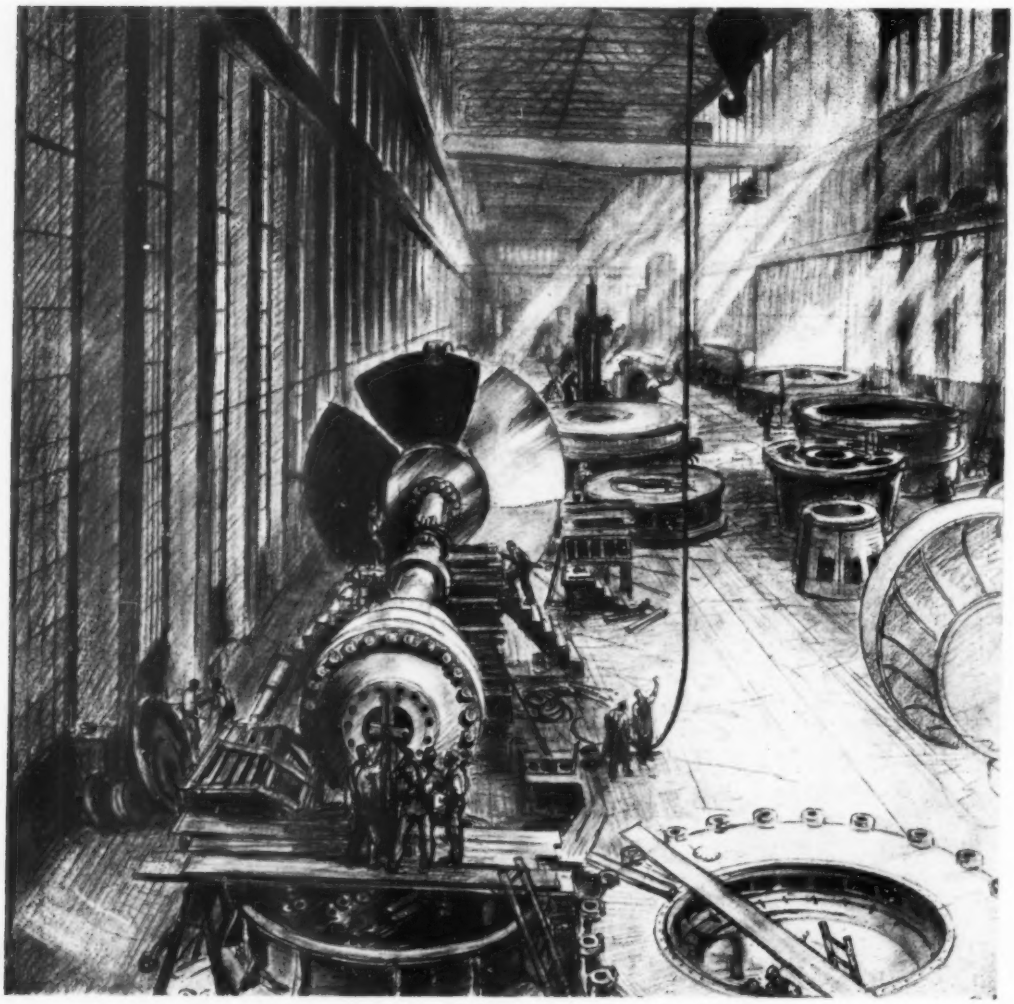

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CONTENTS FOR JANUARY—FEBRUARY 1949

Leading Article: *"Let None Run to Waste"* . . . 1

Editorial Notes 2

The Power Resources of Europe 5
by T. G. N. Haldane, President I.E.E.

The Assuan Dam 11
by Abdel Aziz Ahmed, D.Sc. (Eng.), M.Inst.C.E., M.I.E.E.

Civil Engineering Aspects 17
by Rolt Hammond, A.M.I.C.E.

Inauguration of the Scottish Scheme 22

The Severn Barrage 24

Developments of Intake Works and Surge Tanks . . 25
(with folding plate) by Dr. Charles Jaeger

British Hydromechanics Association 30

Canada's Big Schemes 31
by a Special Correspondent

World Power Conference 34

The Karapiro Station, New Zealand 36

From the World's Press and Technical Institutions . . 41

Contractors' Notes 42

Science in Industry: B.T.H. Summer School 44

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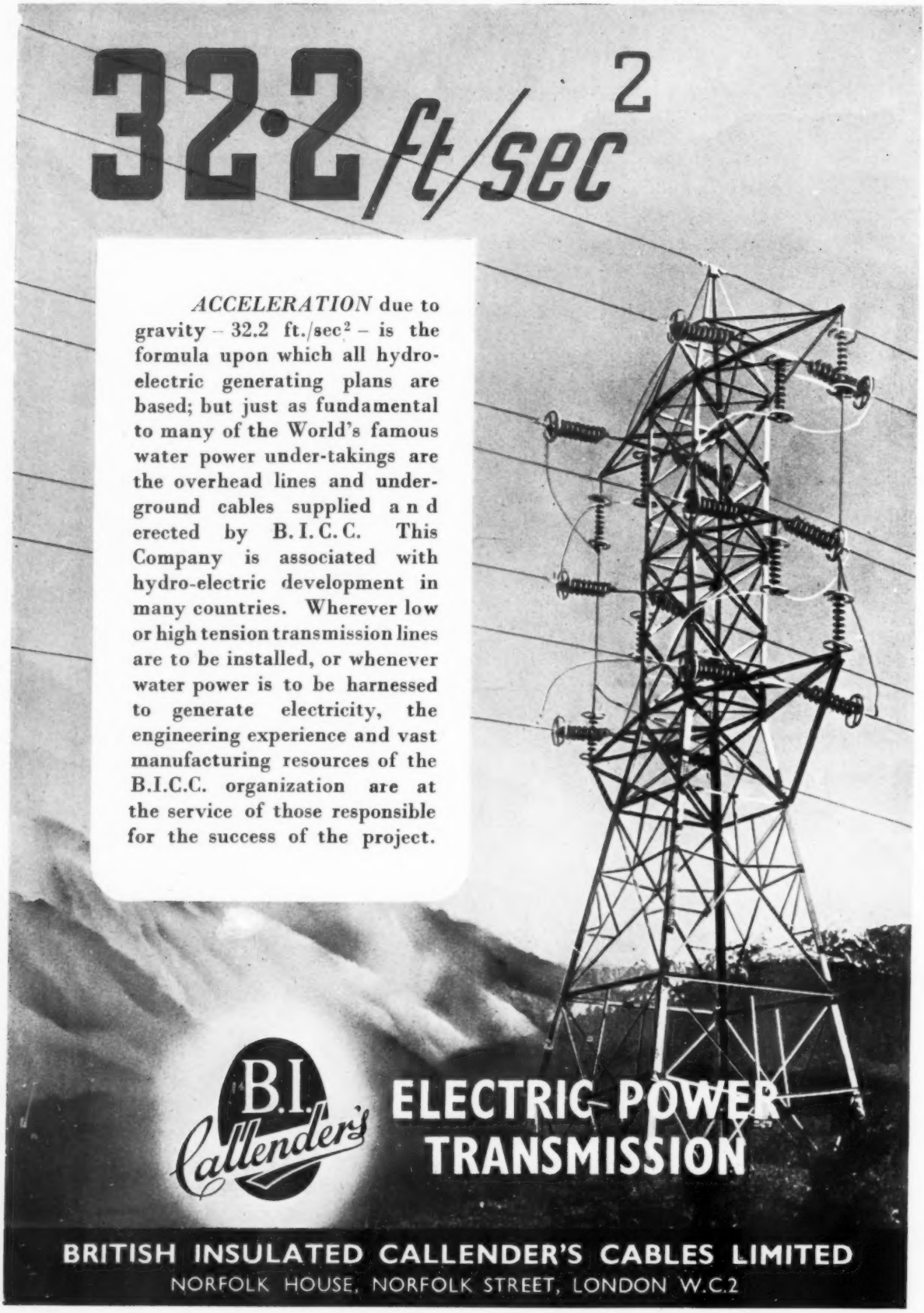

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"Let None Run to Waste"

SINCE the dawn of history the labours of mankind have been eased by water power. It is the oldest source of mechanical energy in the world: progressively its abundant potential has been harnessed . . . in the Nile, Euphrates and the Yellow River . . . mountain torrent and tide.

After centuries of development the crude wooden float wheel, which first lifted water to a thirsty land, was transformed into the majestic turbine of to-day. Even in this atomic age we appreciate, perhaps more than ever before, the true importance of water power; indeed, there is plenty of evidence to support the oft-expressed view that the full development of hydro-electric resources is an essential requirement of modern civilization.

In contemplating the future, men's minds turn to the possible sources from which electric power can be drawn; and it is not without significance that the first year's programme of the European Recovery Plan, which is being made possible by Marshall aid, provides for an acceleration of electricity production from hydraulic sources. But it is not only Europe that needs abundant and cheap electricity to improve industrial production and to make lighter the burdens of the people. Wherever civilization marches the need is great and urgent. Water is everywhere; very often it can be used for the generation of power, and the State is indeed fortunate that has potential hydro-electric resources. The maxim must be: Let None Run to Waste.

But all too frequently is the generation of electricity considered as an end in itself. Steam-produced power has been used where it was needed, with little regard for the extinction of local resources or to the strategic placement of power plants in relation to the national economy. Water power resources have been developed as and where required, in some cases, without consideration of the overall needs of the community for water, irrigation, navigation and community rights; and, moreover, they have sometimes been planned wastefully, to operate as self-contained units without regard to the possibility of helpful inter-connection with thermal systems. Oil engine driven plants have been independently installed by the smaller users, causing uneconomic operation by removing small, though valuable, portions of loading from larger systems.

The development of high-tension transmission systems, enabling vast quantities of power in bulk to be sent from remote mountainous areas to the industrial cities on the plains, allows power to be generated almost anywhere within, and even beyond, the confines of national frontiers. Thus power planning can be divorced from purely local considerations —if not from strategic ones. The operation of thermal plants at their highest efficiencies can be co-ordinated with the use of far-distant hydro-power installations; and the harnessing of rivers and waterfalls, of a kind that at one period would have been thought uneconomical as independent units, can now be considered in relation to a power network as a whole. Often it will be found that the economic aspect of these co-ordinated schemes is altered when viewed from the wider angle.

There is still a broader outlook which considers the use of nature's reserve of energy in the form of water in regard to all aspects of man's needs—not only the power for his industry, but the vital sustenance for his agriculture, the essential "element" without which he cannot live. Therefore we look forward to a time when power commissions will produce large scale overall plants; that such vision can come true is shown by the example of the Tennessee Valley Authority, and by schemes which, if not yet in practical form, are being considered by the Governments of India and Egypt.

We do not close our eyes to the future use of atomic power for generating electricity, but authoritative esti-

mates suggest that it is unlikely, for economic reasons, to replace more than a quarter of our present coal consumption; and moreover, the sources of atomic energy, like coal and oil (as far as our present knowledge extends) are finite. Thus the world will turn more and more to water as the permanent source of its electric power. Nearly half of all electricity generated now comes from hydro-electric plants, and the percentage is slowly rising each year. Even so, of the world's estimated potential of 700,000,000 horse-power, only about 12 per cent. has yet been developed for commercial use.

Thus we go forward with confidence in *WATER POWER*, supported by all who have faith in the gigantic schemes of man's undertaking—and we hope to contribute expert knowledge on the subject, while providing a medium for the exchange of views among all concerned with its planning, development and use.

Message from Australia for "Water Power"

THE Premier of Victoria, the Hon. T. T. Hollway, M.L.A., writes:—"Holding the view that water is power—the key to our future development—I believe that it is impossible to give too much prominence to this great servant of man.

"I am, therefore, delighted that a new technical journal devoted to hydro-electric development has been launched in Britain."

The Government of Victoria is now engaged in completing the largest hydro-electric project—the Kiewa scheme—yet attempted in the Southern Hemisphere. This will have an installed capacity of 289,000 kilowatts, and cost over £25,000,000. A survey has also been completed for a still larger project, the harnessing of the Snowy river, which is estimated to produce 1,750,000 kilowatts. Three Governments (the States of Victoria and New South Wales, and the Commonwealth Government) will combine in exploiting the vast resources of this mountain stream, which is fed from a reservoir of snow. "I mention these two projects to show how intensely interested Victoria is in hydro-electric works.

"I believe that water power will be the answer to the problem of fuel production in the future; that it will be the key to expanding industry. Water has always been a tireless worker. It always will.

"May *WATER POWER* help to promote international understanding, and pave a way for the fuller development of one of nature's greatest gifts—'white coal.'"

Some problems of Production

A recent Press visit to the industrial Midlands of Great Britain, in the course of which two electrical factories were visited, gave publicity to a statement by the Electrical Commissioner to the Government of India on the power needs of the country. He stated that among other necessities India would need nine units of hydro-electric plant.

Technical correspondents on the visit saw how little could be done in spite of considerable pressure from all sources to speed up the production of large scale generating plant. The large amount of apparatus, together with the high standard of checking and testing which were necessary at every stage, meant that skilled labour for that type of work could not possibly be diluted.

India has been considering proposals for the establishment of factories on her own territory for the manufacture of generating plant. How long it would take to train men to work all the precision machinery needed for the manufacture of steam and water turbines is a matter for conjecture; but further, the tour of the Midlands showed that not only must the works be fully staffed by highly skilled labour, there must be, at every stage of production, highly developed background industries. These would produce the machine tools, foundry equipment, measuring devices, and handling gear — apart from the actual raw materials themselves, steel, copper, mica, rubber, and other ancillary products, all needing works which in themselves have required very many years of research and practical development.

Thus it would seem likely that India and other oversea territories contemplating the manufacture of hydro-electric generating plant, will have to rely for many years on the established industrial countries for completed units—and still longer for the background industry products which form so essential a part of all modern power plant.

Six-Nozzled Impulse Turbine

IT is claimed that the first 62,000 h.p. water driven turbo alternator to be installed at the British Columbia Electric Railway Company's Bridge River plant will be the first in the world to utilise six nozzles on an impulse turbine. The casing conveying the water to the jets is 66 inches in diameter at the large end.

Tummel-Garry Project—Errochty Contract

THE North of Scotland Hydro-Electric Board has announced that the contract for the civil engineering work on the Errochty Section of the Tummel-Garry Project (Constructional Scheme No. 2) has been placed with Messrs. A. M. Carmichael Ltd., Edinburgh.

The Errochty Section of the project will utilise 86 square miles of catchment area comprising the upper waters of the Rivers Bruar, Garry and Errochty. This contract includes the construction of 12 miles of collecting tunnels and aqueducts bringing water from the Bruar, Edendon and Garry into a new reservoir, three miles long, on the upper Errochty. The dam creating this new loch will be 1,310 ft. long and 127 ft. high. A feature of the scheme is a tunnel over five miles in length from the Errochty reservoir to the generating station on the shores of Loch Tummel. This tunnel will lead straight to the power station without any external pipeline; the generating station, too, will be mainly, if not entirely, underground. In the first instance Messrs. A. M. Carmichael will concentrate on

constructing the main tunnels, dam and power station so that generation can commence even before the outlying collecting aqueducts are completed.

The plant of the Errochty station will consist of three 25,000 h.p. vertical shaft Francis turbo-alternators of Boving design which will be built by John Brown & Co., Clydebank. The alternators will be supplied by the General Electric Co. and the main transformers by Bruce Peebles & Co., Edinburgh. Sir Alexander Gibb & Partners are the civil engineering consultants. The electrical and mechanical consultants are Messrs. Merz & McLellan.

Asia's Untapped Power Resources

IN its present form the recovery plan for Asia, outlined to the session of the Economic Commission for Asia when it met in Australia, is necessarily somewhat nebulous, because of the generally unsettled conditions. None the less, it is gigantic in conception, and illustrative of the immense potentialities now awaiting exploitation in the continent. Financially it is astronomical, calling for £3,400 million, or over 13,500 million dollars. Of this total approximately £1,000 million is for a wide variety of transport purposes, while projects for electric power expansion are placed, in terms of expenditure, at between £300 million and £400 million. Power under these schemes would be obtained largely from hydro-electric undertakings, and the plan in this respect may be said to mark the first serious consideration given to Asiatic development of water power resources on the grand scale. When completed these works would far more than double the present capacity of 4,000,000 kW, though it may be many years yet before such a point is reached.

Shortages—Water and Coal Compared

POWER plant shortages hamper industrial development in Canada. There, of course, with the enormous potential of water power, those shortages refer almost exclusively to hydro-electric generation. In Sweden an unusual drought has caused power rationing in a country which relies to the extent of nearly 95 per cent. on water power; while a similar condition has existed in New Zealand. In Catalonia, in Spain, and elsewhere, engineers have been so desperate about the empty hydro-electric dams at times of drought that they have bombarded the air over the catchment areas with carbonic snow, which they hoped would break up the clouds and produce rain.

In Great Britain the power shortage has been an equally pressing national problem, but for a different reason. Here a shortage of plant, due to the wartime ban on the extension of generating facilities, is responsible for the present position in which power cuts are inevitable each winter for some years to come.

But the vast difference between the two types of shortage is apparent when the inherent advantages of water power are examined. Every unit of hydro-plant installed, for instance, on a Canadian river will run smoothly for a long life-time, and its efficiency will scarcely alter throughout those years. Moreover, if the surveying has been carried out in the light of recent knowledge the unit will never fail through any shortage of its prime source of energy. In Britain much of the coal-fired plant now being installed must of necessity be used to replace inefficient and out-of-date plant, which has been run for a period exceeding its economic life. The reserves of coal, though large, are limited: to generate electricity by burning coal or oil is no final answer to the power problem.

Italian Research on Turbines and Draught Tubes

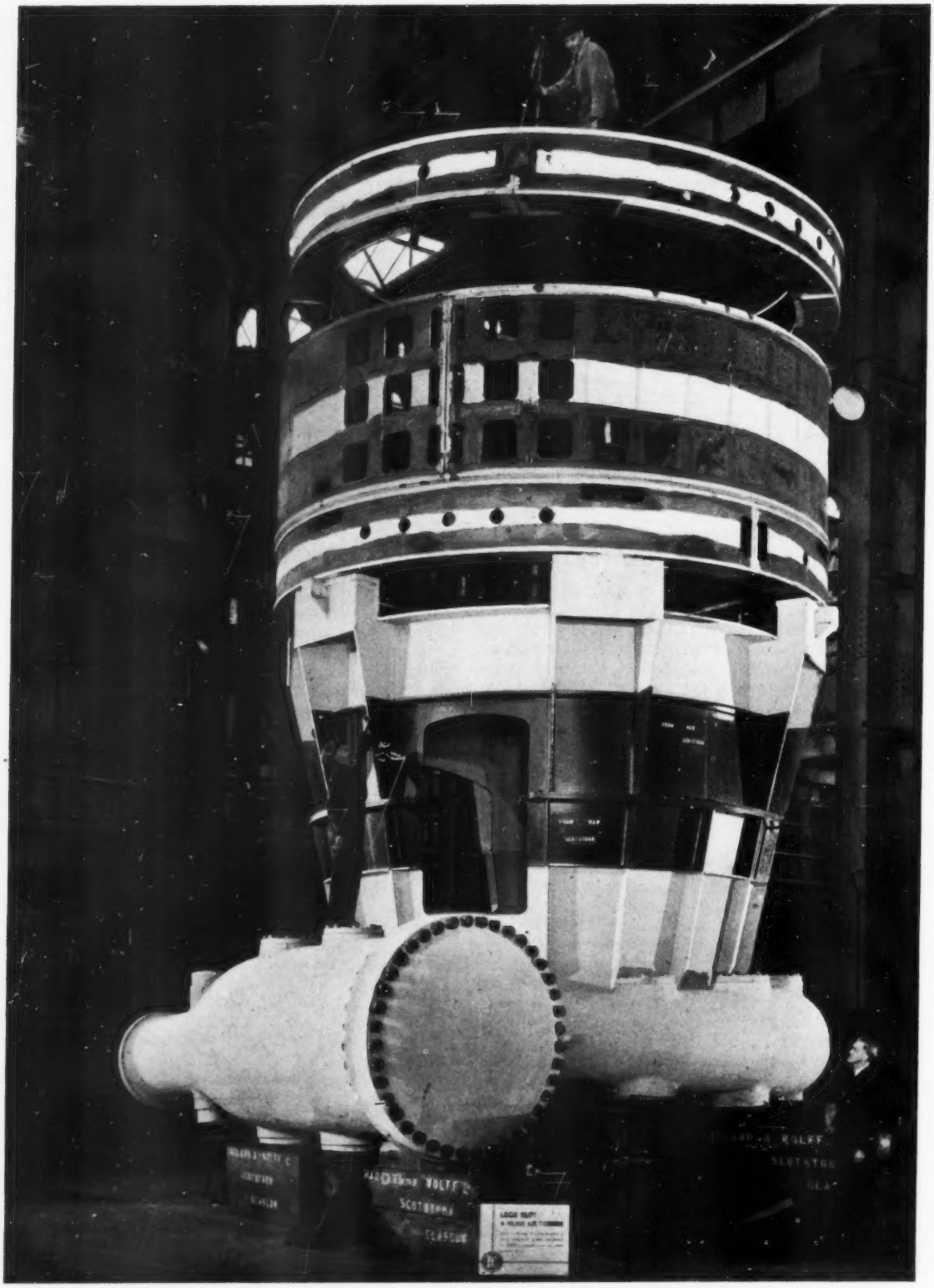
THE Machinery Institution of the University of Padua in Italy has performed some valuable work on various types of draught tubes for water turbines, and on the shape of blades for both Francis and Kaplan types. Of special interest were the extensive tests which correlated the performances of models and of full-scale examples. Care was taken in the models tested to simulate the surface roughness of the full-scale runners. A number of formulae were evolved which assisted the investigators in predicting, with great accuracy, the results of full-scale operation from model tests.

Hydro-Electric Statistics Inadequate

ACCURATE statistics are of vital interest to all engaged in hydro-electric projects; it is therefore surprising to find that little accuracy really exists, and how much loose talk there is about potential hydro-electric resources. While browsing in an engineering library it is easy to find widely differing estimates of hydro-electric potentials existing not only for such relatively unsurveyed parts as the Tibetan mountain ranges and the jungles of Central Africa but also for the most carefully mapped and surveyed countries in the world. Further, the bald figures indicating expected h.p., or in some cases developed h.p. from existing stations, take no account of the fact that little of this power may be in the vital form of " firm " kilowatts.

The latest statistical Year Book of the World Power Conference giving information on resources and annual statistics for 1936 to 1946 is an illuminating document when studied from this aspect. Although it is an invaluable book which has been carefully prepared, there are many gaps in its hydro-electric columns, where a " U " indicates that the figures are unknown or are not compiled. One of its best features, however, is the fact that it does give the developed power in a manner which tells the true availability of the station. Columns headed " Q.95 " and " Q.50 " indicate the output at 95 per cent. and 50 per cent. respectively of maximum flow; and a third column gives the gross capacity of the power sites at the arithmetical mean flow.

The bold statement that a hydro-electric station has " a capacity of 120 MW " is not sufficient for the engineer; there is a great deal more he needs to know, and we hope in due course to initiate a system of presenting statistical information which will give the most exhaustive and accurate picture of the true potential of hydro-electrical installations throughout the world.



32,500 kW turbo alternator for Loch Sloy power station during assembly

The Power Resources of Europe

By T. G. N. HALDANE, President of the Institution of Electrical Engineers. Experience has indicated the advantage of combined generation of electricity by hydro and steam plant; consideration is given here to the practical and economic aspects of such interconnected systems.

Insistant sur la nécessité de n'épargner aucun effort pour satisfaire au besoin, en Europe Occidentale, d'une production d'électricité accrue, en développant les installations tant hydro-électriques que thermiques (brûlant des lignites), l'auteur étudie certains problèmes ainsi posés. Entre autres le coût d'un tel developpement, lequel, dans le cas d'installations hydro-électriques, est normalement bas comparé à celui d'usines à vapeur équivalentes. L'application de ce principe rencontre des complications pratiques qui exigent qu'on tienne compte avec soin, aux points de vue économique et pratique, des facteurs de charge minimum possible.

Instando que todo esfuerzo debe hacerse para satisfacer la demanda Europa para una producción aumentada de electricidad por medio de una mayor explotación de fuerza hidráulica y de las agusas termales quemando el carbon, el autor discute varios problemas que se presentan. Entre ellos se encuentra el costo siempre en aumento de la provisión de las instalaciones generadores, lo cual, en cualquier proyecto hidráulico, es usualmente bajo en comparación con el costo correspondiente de genedores por medio del vapor. Dice el autor tambien que hay complicaciones prácticas en la aplicación de este principio, necesitando cuidadosa reflexión.

ADEQUATE power resources are vital to the material reconstruction of Europe. Even before the war Great Britain and other Western European countries were much under-mechanised as compared with the United States of America, with correspondingly low industrial productivity per head of working population. As a rough estimate this productivity in the United States was, before the war, about twice that of Great Britain while the horse-power per head of working population was also about double. Between 1938 and 1947, productivity per man in the United States manufacturing industries increased by about 27 per cent., while in much of Europe it is still below pre-war level. Consumption of electricity in the United States has increased by 100 per cent. during the same period, whereas the increase in Western Europe (excluding Germany) is only about 50 per cent. Moreover, this increase in Europe has been achieved only by extreme pressure on the very inadequate amount of generating plant available.

Fig. 1 shows electricity production and requirements up to 1953 as estimated by the Committee on European Economic Co-operation. Although Fig. 1 shows requirements and production balancing about 1952/53, it must be regarded as doubtful whether this programme will be achieved. Requirements may very possibly exceed those shown on the curve, particularly if increase in mechanisation can, as it should, be speeded up. Also there may well be delays in carrying out the generating plant programme visualised by the Committee. This programme involves an increase of some 30 million kW between 1948 and 1953 and includes nine international projects in Italy, France, Switzerland, Austria and Germany, of which six are hydro-electric, one geothermic and two will use brown coal. These international projects are designed to contribute to the requirements of countries other than those in which they are built. They will, therefore, involve transmission across frontiers.

The location of the main existing and future energy resources of Western Europe are shown in Fig. 2. The shaded areas represent the chief water power regions, most of which are as yet only partially developed. Particularly in the north and south-east there are very large undeveloped water power resources. The black areas represent the hard coal resources of Western

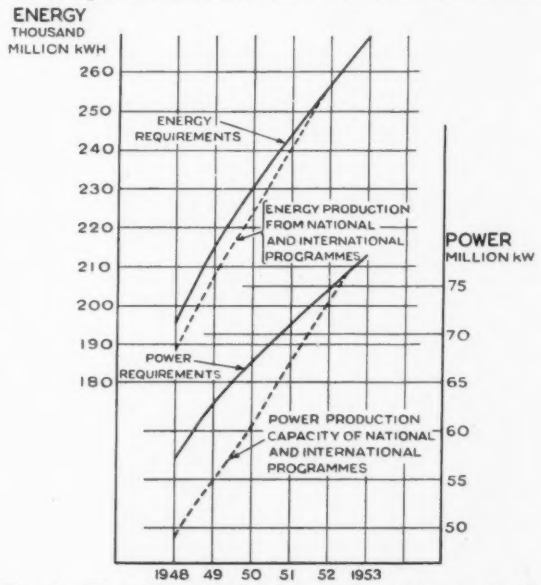


Fig. 1. *Electricity production and requirements of Western Europe*

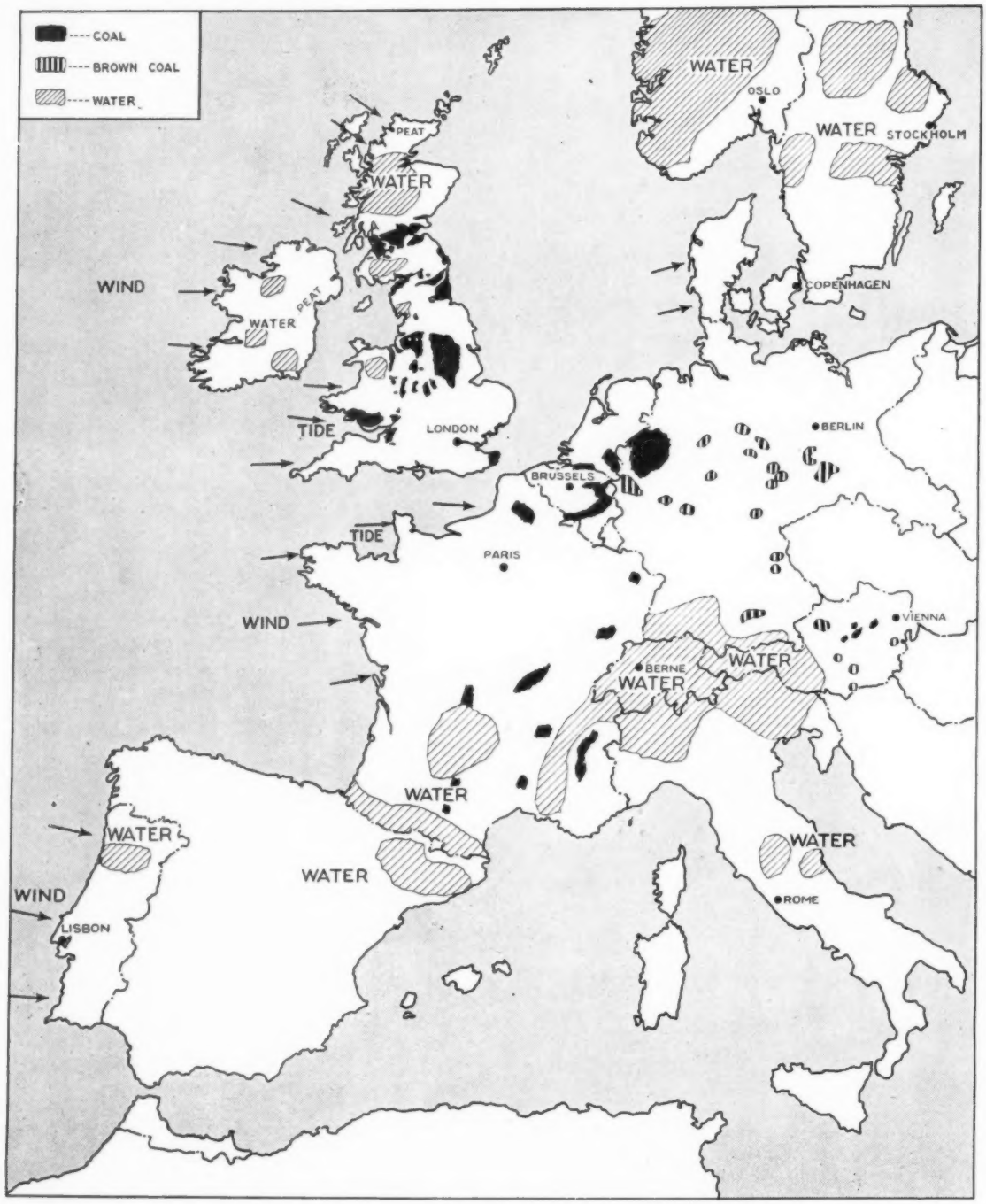


Fig. 2. *Energy resources of Europe*

Europe, but it must be remembered that there is an acute shortage of hard coal and this is not one of the sources of energy which can best be spared, since hard coal is urgently required for many purposes other than power production. On the other hand, the brown coal of Germany is eminently suited for power production purposes since, practically speaking, it cannot be used for any other purpose.

It follows that every effort should be made to meet Western European requirements by further development of water power and of thermal stations burning brown coal. Both these resources are fixed in geographical position, since the cost of transporting brown coal over any appreciable distance would be excessive.

Likewise, consideration should also be given to

future possibilities represented by tidal and wind power. Of the tidal schemes the most important are those in the Severn Estuary and on the coast of Brittany, the latter being capable of a very large contribution to European requirements. Wind power is at present the subject of intensive study both in this country and in France, but is likely to be limited to sites along the western seaboards of Great Britain and France.

It is clear that if the power resources of Europe are to be developed in the most economic manner there is an urgent need for a very high voltage European Grid system which will perform two functions—namely, transmission and interconnection. As regards transmission, it will be necessary to carry

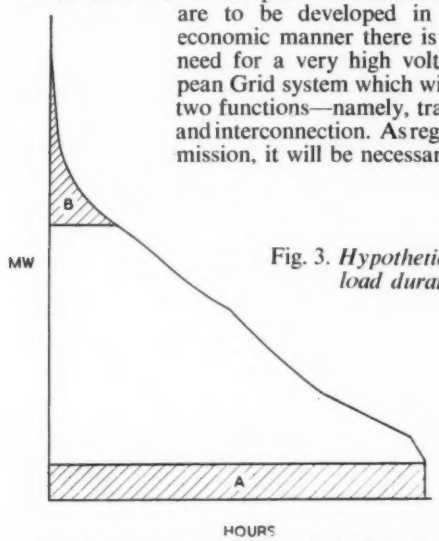


Fig. 3. *Hypothetical annual load duration curve*

water power generated in the relatively remote regions of Scandinavia or S.E. Europe to the principal load centres, particularly in Northern France, Belgium and along the Rhine. In Great Britain it is necessary to transmit the power in Northern Scotland to the industrial areas lying to the south.

As regards interconnection, it is desirable to link together the existing generating plant in the main industrial areas, so enabling substantial economies to be achieved both in the amount of generating plant required and in running cost. This is the function which has been so successfully performed for the past 20 years by the British 132 kV grid. Interconnection reduces the amount of spare or standby plant required and enables generation to be concentrated in the most economical stations.

For the longer distances and greater loads involved in the case of Western Europe the grid system would require to operate at a voltage not less than about 400 kV. A.C. transmission at this voltage is already a practical and economical possibility and at the present

Horsehoe tunnel (24ft. dia.) of Clunie Scheme

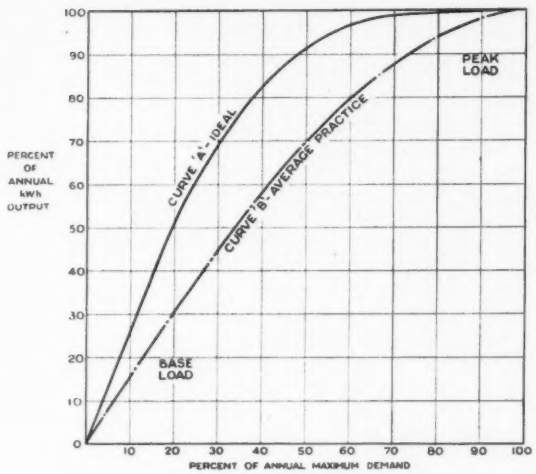


Fig. 4. *Integrated duration curves*

time a 380 kV transmission system is being constructed in Sweden enabling some 300,000 kW of water power to be transmitted over a distance of 600 miles from north to south. Very high voltage D.C. transmission may also become both technically and commercially feasible in due course and great attention is being paid to this possibility at the present time. D.C. transmission is particularly attractive in cases where it is necessary to transmit by underground or submarine cable.

Hydro and Thermal Plant Combined

In Western Europe much of the water power is seasonal, being at its maximum in summer when the snows of the high mountains are melting and at a minimum in winter. This is an unfavourable characteristic and in Great Britain we are fortunate in that

our water power resources in Scotland and elsewhere tend to be at a maximum in winter when the demand is also greatest. To compensate fully for the seasonal characteristic of European water power by the construction of storage dams would involve very great expenditure and a better method is to combine hydro and thermal generation.

Experience throughout the world has indicated the advantage of combined generation and this experience can, for the most part, be divided into two categories:

(1) Systems in which the bulk of the plant is hydro-electric, and

(2) Systems in which the bulk of the plant is thermal.

In category (1) the water power stations are designed normally to operate at moderate or fairly high annual load factors, the thermal stations being used only for peak load purposes or at times of water shortage. In category (2) it is usually advantageous to develop the water power stations as peak load stations operating at a comparatively low annual load factor but making a large peak contribution to the kilowatt requirements, the reason for this is that in a hydro-electric scheme the cost of storage usually forms an appreciable proportion of the total. As this item of cost does not depend to any great extent on the annual load factor (except at very high load factors), the capital cost per kilowatt is less for a low than for a high load factor.

For most projects it will be found that the incremental costs resulting from reduced load factor (*i.e.*, cost of increased amount of installed plant, larger conduit and transmission) are less than the corresponding capital cost of increasing the installed capacity of a thermal station. Hence, as already mentioned, it is usually advantageous to develop the water power project at the lowest practical load factor at which the system can absorb the energy. A further advantage which arises from the increased generating capacity provided in a low load factor installation is that spillage can be reduced at times of high run-off. A typical example of the effect of reducing load factor is shown in Table 1.

Sweden is an example of category (1) in the table and Great Britain of category (2). In Great Britain some of the earlier hydro-electric stations, such as Tummel Bridge and Rannoch, were designed for relatively high annual load factor operation (of the order of 50 per cent.), but after the construction of the grid and the consequent interconnection of thermal and hydro stations it became possible to design hydro-electric projects for low load factors. This principle was applied to the Galloway development, which is designed for a load factor of about 20 per cent. The principle has been further applied in the case of the North of Scotland Hydro-Electric Board's stations, the design load factors of some of which are shown in Table 2.

Although the incremental cost, measured either in money or steel, of increasing the amount of generating plant in any hydro project is usually low compared with the corresponding cost of steam generating plant,

TABLE 2

North of Scotland Hydro-Electric Board's Stations Load Factors and Distances

Station	Load Factors %	Approx. direct distance from load centre. Miles
Sloy	10.7	35
Errochty	15.7	50
Clachan	20.4	40
Lawers	27	45
Clunie	28.7	55
Lairige	33	40
Quoich	39	90
Grudie	40	120
Invergarry ...	43	85
Invermoriston ...	43	95
Luichart	43	120

Tummel-Garry Project: A view of the tunnel outfall portal

TABLE 1

Cost of Production from a typical Hydro Installation at different Load Factors

Installed capacity kW	8,000	11,000	14,000	21,000	32,000
Average annual output million kWh	37	37	37	37	37
Load factor %	53	38	30	20	13
Annual cost of production ...	£60,000	£62,000	£65,000	£78,000	£95,000
Annual cost per kW installed	£7.5	£5.6	£4.6	£3.7	£3.0
Estimated annual revenue from sale of kW and kWh ...	£64,000	£71,000	£78,000	£96,000	£123,000
Excess of revenue over cost of production	£4,000	£9,000	£13,000	£18,000	£28,000

Petlochry Dam and Power Station of the Tummel-Garry Project

there are considerable practical complications in applying this principle. Although these complications do not vitiate the principle, they necessitate very careful consideration as to the lowest load factors which are possible both from the practical and economic aspect. Briefly, the problems are as follows:—

(1). In order to reduce the overall fuel cost of the steam stations in any system to the theoretical minimum, it is necessary that the plant working at the lowest fuel cost per kilowatt-hour generated should take the lowest position in the annual load duration curve for the system and that the machines should, as far as possible, be arranged within that curve in ascending order of their fuel cost. By this means the oldest and least efficient stations will normally take the peak loads only. Thus in an expanding system a new base load steam station would be expected to occupy position 'A' in the hypothetical load duration curve shown in Fig. 3. The effect of this would be to displace all the remaining stations further up the curve, each of which will generate a smaller number of units than before the new plant was introduced. A reduction in the average coal consumption for the system results partly from the lower unit fuel consumption of the new plant and partly from the fact that the less economical stations generate fewer units as a result of their displacement up the load curve. The latter saving is somewhat, but only to a minor extent, offset by the sacrifice of effiiciency caused by operation at lower load factors.

If, however, it is desired to introduce into the system a number of hydro-electric stations designed to take the peak loads as at 'B' in Fig. 3, the reverse of the above trend will occur and the old steam stations will be displaced relatively downwards in the load curve, with a resulting increase in average coal consumption due to the increased number of units generated by the less efficient steam stations.

(2). Since the development of low load factor hydro-electric stations tends to exclude, at least temporarily, new high efficiency base load steam stations, the former can only be justified as integral parts of a combined hydro and steam system if they can show a net saving. In order to ascertain what, if any, net saving there may be, it is necessary to make a comparison over a number of years. The comparison is dependent on ability to forecast the future increase in the efficiency of thermal stations on which the whole argument is based. As it is also necessary to know the effect of load factor on the efficiencies of the steam stations and to forecast the trend of the price of coal, the comparison may become a matter of considerable complexity if the circumstances are marginal.

(3). In practice, operating conditions make it impossible to achieve the theoretical optimum use of plant as mentioned above and an examination of steam plant statistics shows that the plant which should carry the base loads tends to run at a lower load factor than theoretically desirable and the plant taking the peak load runs at a correspondingly higher load factor. Amongst the causes of this effect may be mentioned reduced availability of base load plant, due to breakdown, and lack of flexibility of peak load steam plant due to the fact that boilers cannot pass quickly from a banked condition to one of full load. Also there are human errors including a natural tendency to run up the peak load plant ahead of the time when it is actually required. All these factors tend to make the less efficient stations generate more than their theoretically desirable quota at the expense of the more efficient stations

The problem is well illustrated by integrated duration curves, as shown in Fig. 4, the slope of which is proportional to the load factor of the various blocks of power. Curve A is the ideal operating condition in which the most economical machines carry the base load and generate their full desired quota of kilowatt-hours. Curve B is typical of what is actually achieved in practice on an all-thermal system and shows the extent to which the load factors of peak load stations are increased above the desired minimum because of deficiency of the base load stations or for other reasons.

(4). The limitations mentioned above do not, necessarily, apply to hydro plant operating in conjunction with steam plant since the former has a much higher availability. Also hydro plant is more flexible in that it is capable of being run up, synchronised in, and raised from no-load to full-load very quickly. The effect of this is that hydro plant can be relied on by the system control staff for picking up and dropping load in such a manner as to follow very closely the peak variations. The use of hydro-electric power for peak load purposes should make operation of the steam stations easier, since they will be operating within a flat topped daily load curve and violent fluctuations of load will not have to be met. This advantage has, therefore, to be balanced against the disadvantage already referred to in (1).

(5). An independent practical difficulty may arise from the adoption of very low load factors due to the damage which may be caused by the relatively sudden discharge of large quantities of water from the turbines, and unless the particular hydro station is situated on a lake or other large area of water, considerations of river bank erosion and flooding may restrict the load factor to a certain minimum.

Complex Problems Involved

In this country where the proportion of hydro power to thermal power is small, after making full allowance for breakdown, spare plant and maintenance of the steam plant, there would normally be sufficient steam plant available to carry the whole system load during the summer months without reliance on the hydro plant. In that case the hydro stations could generate in summer in accordance with the day-to-day run-off and without drawing to any great extent on storage. Because of the present acute shortage of generating plant there is actually a shortage of steam plant even in the summer months. Thus the hydro plant may have to be relied on all the year round, but in general it should be possible to make the seasonal variations in load on the hydro stations conform reasonably to the seasonal variations of rainfall in this country with consequent saving in the amount of storage required.

In the foregoing discussion of the advantages of peak load operation of hydro stations it has been assumed that transmission distances are moderate. The greater these distances the greater becomes the overall incremental cost of installing additional plant. Hence there is a natural tendency, which can be noted from the examples given in Table 2, for the load factors to be lowest in the case of hydro stations which are nearest to the load centres and require the least amount of transmission.

It is not possible in so short a space to deal fully with the complex problems involved in the combined operation of thermal and hydro stations. The foregoing may, however, give some indication of the character of these problems which are constantly increasing in complexity as the size of the interconnected systems grows and as new types of generating plant are introduced. For instance the gas turbine, with its special characteristics, will create an additional problem, as also may the future development of tidal power. Wind power may also some day add another complication. But as these complications increase so also does the economic reward for their proper solution. It is apparent that great development of systems of automatic control, indication, measurement and computation will be required and will be economically justified.

At present we, necessarily, think of Great Britain and Western Europe as two distinct power problems, but the time may come—perhaps not very far distant—when the great thermal system of this country will be linked to the mixed thermal and hydro system of the continent, with considerable advantage to both sides of the channel.

Welsh Power Schemes

THE British Electricity Authority has considered a report on possible future developments of hydro-electric resources in North Wales which would have a total estimated annual output of about 520 million units. The present annual production of electricity in North Wales amounts to 110 million units, and nearly 300 million more have to be imported from the National Grid System. Thus, with existing plant and the output from the proposed schemes, which have been approved in principle, the generation of electricity would be increased to about 630 million units a year—a valuable contribution to the needs of an area with considerable industrial development in hand.

The schemes which were proposed by the consulting engineers, Messrs. Freeman, Fox and Partners and Mr. James Williamson, include extensions to the existing catchment area for the Dolgarrog hydro-electric station, and the provision of additional generating plant. Surveys are also in hand for an extension of the catchment area for the Maentwrog merited further consideration:

The following major hydro-electric projects were recommended along with some minor schemes which merited further consideration:

Upper Conway.—To utilize the high ground of the Upper Conway and Afon Machnoas water collecting areas for two power stations at different elevations.

Mawddach.—Here the Afon Mawddach and tributaries to the west flowing to the River Eden would be utilized to generate electricity through three power stations.

Rheidol.—This scheme would use the heights of Plynlimon in Mid Wales as a gathering ground and water collected in the Afon Rheidol would be passed through three stations.

Snowdon.—A small power station, Cwm Dyli, already exists. The present gathering point in Llyn Llydaw for this station would be diverted to a new power station, and the Cym Dyli station would receive its water from an area further to the North. In this scheme five power stations are proposed.

Ffestinoig.—The water run-off source from some of the hill ranges in the Blaenau Ffestiniog area would be fed to three power stations.

Nant Ffrancon.—This proposal for an area south east of Bethesda makes use of Llyn Idwal and Llyn Ogwen as local storages, which would be augmented by diverted water for a power station to be installed in the Valley of the Nant Ffrancon. Two power stations are proposed in this instance with the second and larger station located near sea level in Conway Bay, near Aber.

The cost of the six major schemes as estimated by the consulting engineers, with adjustments for present day prices, would be about £20 million.

The Assuan Dam

BY ABDEL AZIZ AHMED, D.Sc. (Eng.), M. Inst. C.E., M.I.E.E.

In this authoritative article the chairman of the Hydro-Electric Power Department, Egyptian Government, discusses the Assuan Dam project, the Second Cataract hydro-electric scheme, and the possibility of using the Qattara Depression as a source of power generation.

La prospérité future de l'Egypte dépend dans une large mesure de la mise en valeur de sa houille blanche; celle-ci doit servir les besoins des industries mécanisées et d'autres objets d'ordre général; mais, beaucoup plus importante encore, l'irrigation demande une abondance de puissance hydro-électrique. Dans l'article ci-dessous, un expert du gouvernement décrit les plans ambitieux en vue d'aménager les eaux du Nil et d'autres sources latentes de puissance. Les sources potentielles de houille blanche de beaucoup les plus importantes en Egypte sont le barrage d'Assouan, la deuxième Cataracte et la cuvette de Quattara capables de produire au total 1 164 000 Kws; les projets sont à étude.

La prosperidad del Egipto depende en sumo grado de la provision abundante de fuerza motriz generada por el agua para servir su industria mecanizada y otros fines generales, pero quizás el mas importante es una provision de fuerza hidro-electrica que sea necesaria para el sistema de riego. En la sección un oficial del Gobierno explica los proyectos ambiciosos para aprovechar la fuerza del rio Nilo y otros fuentes de fuerza. En mucho los fuentes mas potenciales de la fuerza generada por el agua en Egipto son la Represa de Assuan, la Catarata Segunda y la Depresión de Quattara, los cuales son capaces de producir juntamente cerca de 1,164,000 KW., y los proyectos correspondientes están bajo examen.

THERE are probably few countries in the world whose future well-being depends so much on a plentiful supply of water power: Egypt needs cheap electric power not only for mechanised industry, municipal and other general purposes, as most countries; but probably more for the expansion of cultivation to cope with the progressively increasing population.

Egypt is practically a rainless country and is entirely dependent for irrigation on the River Nile which supplies her water requirements all the year through. The country embraces a total area of almost exactly one million square kilometres (about 400,000 square miles). The cultivable area consists of narrow strips of alluvial soil bordering the Nile, and over the Fayum Depression and the Delta, comprising altogether roughly 30,000 sq. km. (about 12,000 sq. miles) or about 3 per cent. of the total area of the country.

Irrigation in Egypt is almost entirely carried out by means of free flow canals, where water is maintained at a higher level than the land they served, by means of regulators placed at regular intervals. Cultivation might be carried into the desert land beyond the Nile Valley if electric energy could be made available in abundance and at low cost. But Egypt does not possess natural water falls except to a very limited extent in the province of Fayoum, where so far only a small hydro-electric power station has been constructed having an installed capacity of about 3,000 kW.

However, the Nile level at Assuan, which lies about 1,000 km. (621 miles) from the sea, is roughly 80 m. (260 ft.) above sea level. Theoretically this difference of level can be divided into a series of heads which may be artificially created by damming the river at convenient points along its course. But because of the gradual slope of the river such artificial heads are bound to be small, so that the cost of hydro-electric plant necessary to handle large quantities of water in order to produce appreciable amounts of power would be high in relation to the power generated.

The Nile Barrages

Probably it would not pay to throw special barrages across the river for power generation, but where irrigation demands the erection of such barrages no doubt power could be economically generated therefrom, particularly if the power scheme be incorporated with the barrage during its construction. There are at present four main barrages on the Nile—the Esna, Nag-Hamadi, Assiut and Delta Barrages. So far only the Nag-Hamadi Barrage has been partially electrified. Because of the small heads available at these barrages, varying between 1 and 4 m. ($3\frac{1}{4}$—13 ft.), the total estimated output is only 74,000 kW, with a corresponding energy output of 642 millions kWh annually.

By far the greatest potential sources of water power in Egypt are the Assuan Dam, Second Cataract and the Qattara Depression, which are capable of producing altogether 1,164,000 kW. The Assuan Dam scheme is under construction; the other two projects are under examination.

Assuan Dam Hydro-Electric Scheme

Assuan Dam lies about 6 kilometres ($3\frac{1}{2}$ miles) south of Assuan. It is 2,141 metres ($1\frac{1}{2}$ miles) long and 35 metres (114 ft.) high. It consists of two parts, the pierced dam, about 1,500 m. (1 mile) long forming the western side and containing 180 sluices, and the solid dam forming the eastern side. (See Fig. 1).

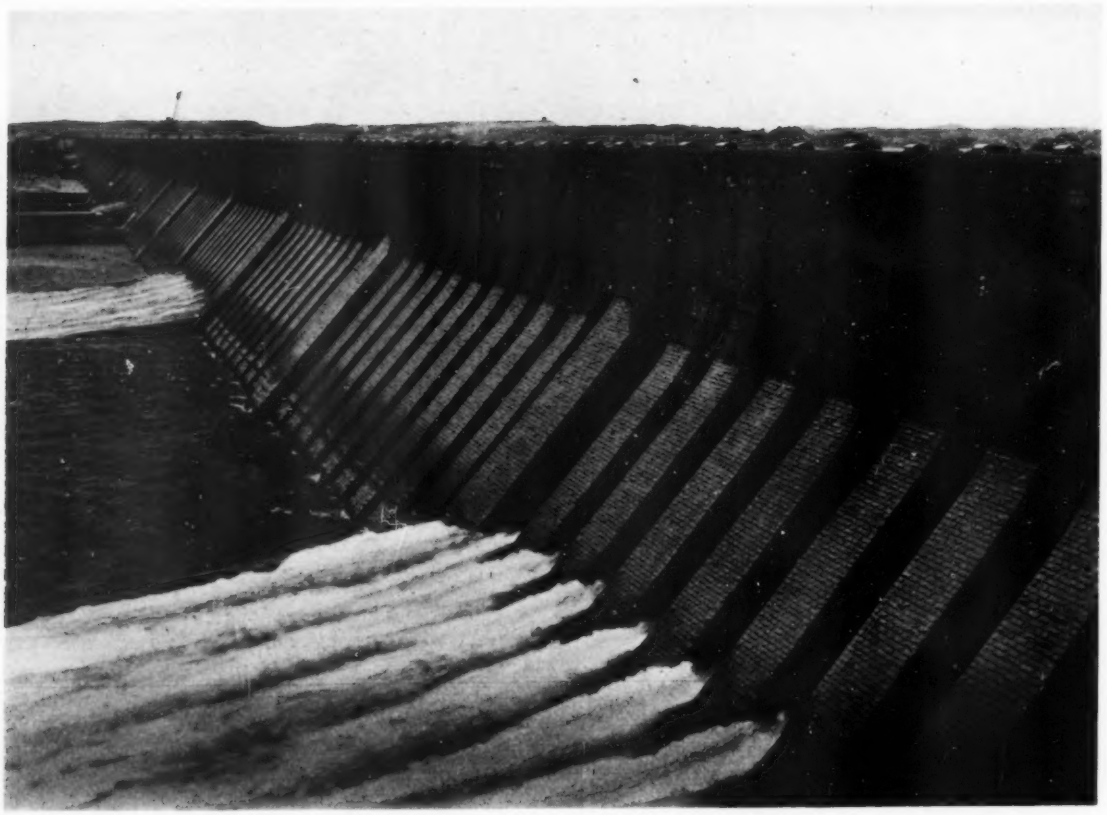


Fig. 1. *The solid dam forming the eastern side*

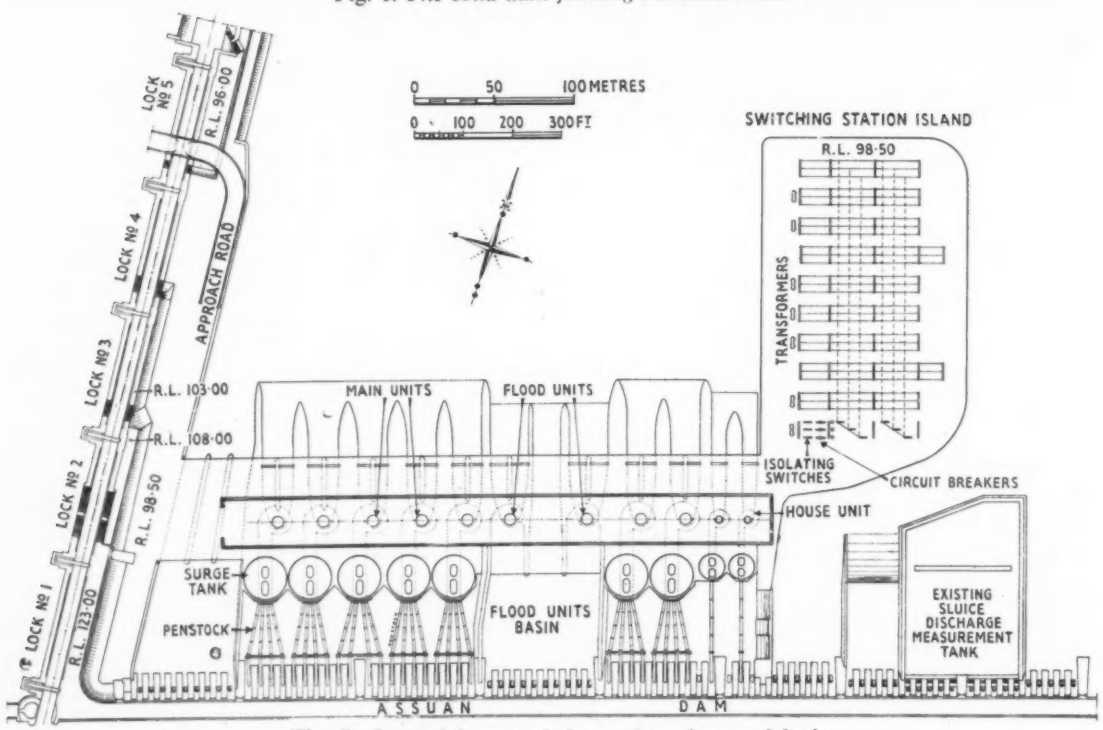


Fig. 2. *General layout of the station, dam and lock*

The Assuan Dam is used for the storage of flood water, which is released when the natural discharge of the river falls below the requirements of irrigation. Because the flood water carries a certain amount of silt in suspension, the present practice is to keep the sluices of the dam fully open throughout the flood season, thus lowering the level in the reservoir to a mere heading up on the sluices of about 4 metres (13 ft.) in an average year, in order to reduce silting. Investigation has, however, been carried on over a number of years with a view to raising the head during the flood season for the purpose of power generation. The results of this investigation show that with a head of 8 metres (26 ft.) maintained at the dam during flood, the amount of silt which is likely to be deposited with the lapse of years would be insignificant. This agrees fairly well with results arrived at by theoretical studies (*See "A method of estimating the maximum possible silt deposit upstream of Dams constructed in silt-carrying rivers," by Abdel Aziz Ahmed—Journal I.E.E., No. 7, June 1941*).

The filling of the reservoir begins towards the end of the flood period, when the water has subsided to a predetermined level, at which the silt content in the river is assumed to have fallen sufficiently to cause no appreciable deposit in the reservoir. Filling usually commences about the beginning of October and continues till the end of January, when the reservoir is completely full. As water is drawn from the reservoir for irrigation purposes the upstream level falls gradually and reaches its lowest level in July, when flood water begins to arrive.

Constructional Features

Unlike other hydro-electric schemes, where the dam is usually built simultaneously with the generating station and often specially for it, the Assuan Dam was built solely for irrigation purposes many years ago, and has become, with the lapse of time, the mainstay of the agricultural economy of Egypt. The hydro-electric scheme had, therefore, to be applied to existing conditions and whatever the layout for the generating station the absolute safety of the dam had to be fully assured.

The method of feeding the turbines has been tackled by several engineers. The present project is probably the first practical layout which, though using penstocks, did not entail the demolition of any part of the dam or any modification whatsoever to the stresses originally acting upon it. These conditions had been laid down by the irrigation authorities and had to be strictly observed.

The insertion of three pipes in each sluice in vertical tiers is a notable feature. With this arrangement as a starting point, the pipes may be connected together in a variety of ways, according to the number of sluices employed to feed each turbine. Fig. 2 shows the general layout of the hydro-electric station, the dam and lock.

Because of the large variation of head, from 33 to 8 metres (107—26 ft.), the use of Kaplan or adjustable-blade propeller turbines is obviously indicated, in order to obtain reasonably high efficiency under all conditions of head and load variations. Four sluices are used to feed each turbine, making altogether 12 penstocks a turbine. These penstocks, each 1.8 metres (70 in.) diameter, are joined together at the entrance to the surge tank, and connected to the turbine through a penstock of 7.8 metres (305 in.) diameter. Fig. 3 shows the hydro-electric station in plan and section.

The power station has been located on the west side of the dam in order to make use of low level sluices for feeding the turbines. The site chosen has the further advantage that the discharge water would

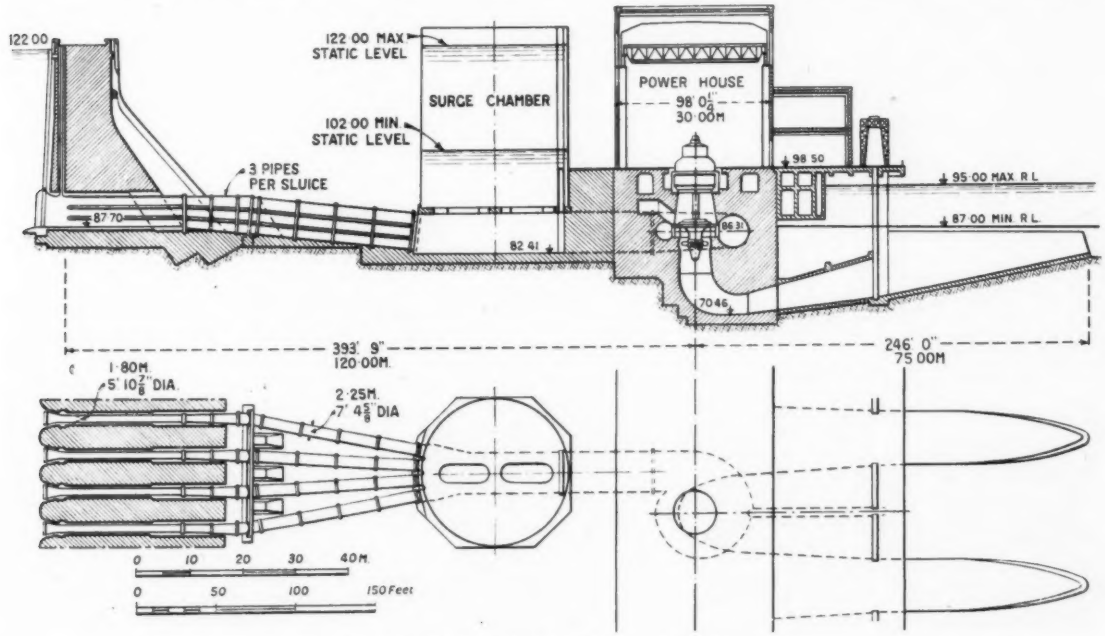


Fig. 3. *The station in plan and section*

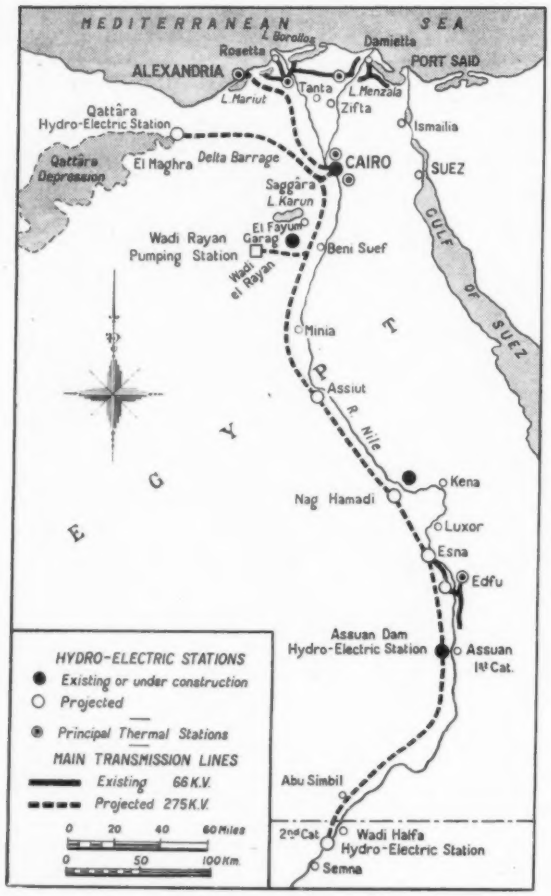


Fig. 4. *Layout of the transmission system connecting the Assuan Dam with existing or projected Egyptian generating stations*

be thrown directly into the western channel which has to be maintained navigable. The total installed power of the generating station is 487,000 h.p. There are seven main vertical turbines, each 65,000 h.p., 100 r.p.m., directly coupled to an alternator having a rated output of 47,000 kW at 0.95 power factor, and 11 kV. Each alternator will be directly coupled to its own transformer bank operating at 11 to 275 kV.

In addition there will be two auxiliary sets of Kaplan turbines, each 16,000 h.p., 250 r.p.m., coupled directly to 11,500 kW alternators.

The 275 kV service has been chosen in order to provide for the future possibility of transmitting power further north to Lower Egypt. Fig. 4 shows the layout of the 275 kV transmission system connecting the Assuan Dam hydro-electric station with existing and projected generating stations in Egypt.

The total installed capacity of the station is 352,000 kW. Under present hydraulic conditions the maximum output will be 260,000 kW. Owing to the large variation of head already mentioned this output lasts about eight months of the year falling to 50,000 kW during the floods. The flood power output could, however, be increased by the installation of low head turbine units operating only during flood. Two such units have been envisaged in the scheme producing together 50,000 kW, thus raising the power available during flood to 100,000 kW. The use of these units is economically justified—the cost per kWh produced therefrom being 0.7 m/m, as compared with 0.4 m/m per kWh produced by the main generators. (*One millieme [m/m] is a 1000th part of an Egyptian pound which is equal £1 0s. 6d. Sterling.).* The distribution of output as well as head and discharge throughout the year is given in Fig. 5.

The total amount of energy available from the power station is 1,645 million kWh which would be increased to 1,748 million kWh after the installation of the two flood units.

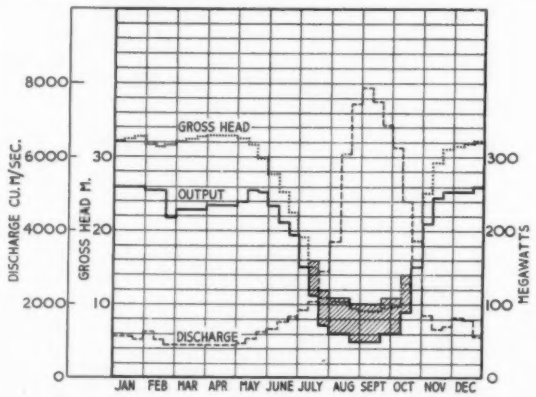
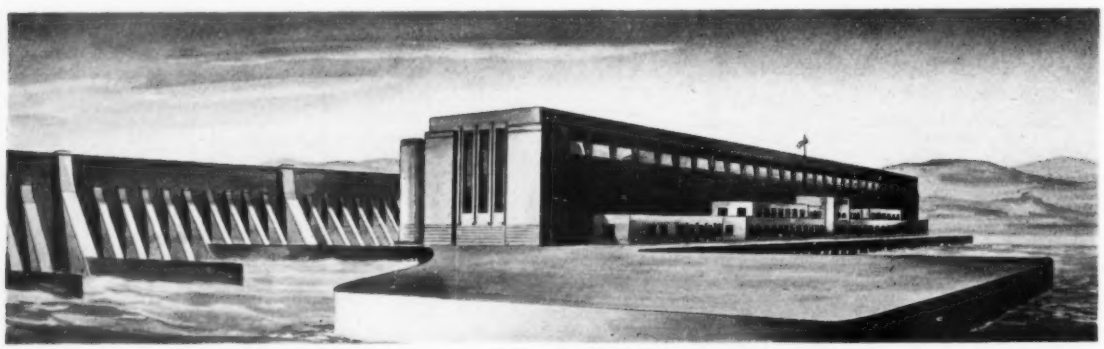


Fig. 5. *Head, discharge and output curves*
Hatched area shows additional energy produced by adding 2 low head units or by increasing minimum level of reservoir from R.L. 103.00 to R.L. 106.00 m.



Artist's impression of the Assuan Dam power house

Excavating boulders by primitive methods

Silting up in the western channel below Sudd

It is evident that there are two kinds of energy available in the first stage from the generating station: (a) seasonal energy of about 210,000 kW, which is available for eight months of the year; and (b) firm energy of about 50,000 kW, which is available all the year round. The market for the seasonal energy would be limited, as is usually the case, to industries, mainly in the electro-chemical or electro-metallurgical

Pool at site of the eastern power house indicating decomposed rock in foundation. The size of the pool can be judged from the figures in the middle distance

groups, whose output could be stopped completely or severely curtailed during the flood season, without detriment to their operation.

New Projects Envisaged

Two such industries have been selected, namely the nitrogen fertiliser industry and the steel industry; the output of the former would be readily absorbed in Egypt, whose demand for fertiliser is ever increasing. The latter has been chosen because of the large deposits in the neighbourhood of Assuan of high-grade ore with an iron oxide content which corresponds to a percentage of metallic iron varying from 16.6 to 33.3. Sulphur is almost entirely absent and the percentage of phosphorus is low, so that the conditions are favourable for the extraction of iron from the ore by electric smelting. The estimated output of these industries is respectively 300,000 tons of 20.5 per cent. nitrolimestone and about 90,000 tons of steel *per annum*. The firm power amounting to 113 million kWh *per annum* would be devoted to the development of various industries in that province.

The Consulting Engineers appointed for the Assuan Hydro-Electric Project are Messrs. Kennedy & Donkin of London, England. They have associated with them for the civil engineering work Messrs. Binnie, Deacon & Gourley of London, Messrs. Gruner Brothers of Basle, Switzerland, and Messrs. Scott & Wilson of London. The Architect is Sir Giles Gilbert Scott, O.M., R.A.

The second stage of development of the Upper Egypt electrification scheme involves the development of the Second Cataract hydro-electric project at Wadi Halfa. Preliminary investigations show that the total output of the station would be about 520,000 kW, and 3,620 million kWh, consisting of 200,000 kW and 1,750 million kWh firm energy available all the year round, and 320,000 kW and 1,870 million kWh seasonal energy available during eight months only. The additional storage water at Wadi Halfa reservoir would allow the firm output of the Assuan Dam hydro-electric station to be considerably increased.

These projects would be linked by a 275 kV transmission system which could at some future time be extended to Lower Egypt, connecting together all the large thermal stations scattered in the Delta and joining eventually with the Qattara scheme in the north-western desert (See Fig. 4).

Qattara Hydro-Electric Scheme

There exists in the west of the Nile Delta a large depression whose maximum length is about 300 kilometres (186 miles) and maximum breadth about 145 kilometres (90 miles). Its lowest point is about 134 metres (435 ft.) below sea level. The area of the depression at sea level is about 19,500 square kilometres and its capacity is 1,170 cubic kilometres.

It is believed that the depression was formed in recent geological times by the excavating action of the wind on soft sandstone rocks. The large quantities of sand removed from the depression are now to be seen as sand dunes on the southern sides of the depression.

The project now under study by the Hydro-electric Power Commission is to utilise this depression for power generation, as originally conceived and very ably worked out by the late Dr. John Ball (*See "The Qattara Depression of the Libyan Desert and the possibility of its Utilisation for Power-Production," by Dr. John Ball—Geographical Journal, Vol. LXXXII, No. 4, October 1933.*).

Sea water would be led from the Mediterranean over a distance of 72 kilometres (44½ miles), first in an open channel 50 metres (162 ft.) wide and then by a tunnel to the edge of the depression, which has a very steep gradient, and hence through a pipeline to waterwheels coupled to electric generators. Assuming a fall of 50 metres, it would be possible to generate 300,000 kilowatts. The influx of water from the sea would be disposed of by evaporation from the lake thus formed at a level 50 metres below the sea's surface. This lake would have an area of 13,500 square kilometres, which is about the same area as the cultivated land of Lower Egypt. The site of the hydro-electric station would be about 200 kilometres (124 miles) from the inhabited areas of the Delta.

Most of the capital outlay for the scheme would be spent in the excavation work for canal and tunnel. The estimated high cost of excavation has been hitherto the stumbling block in carrying out the scheme. But in view of the experience gained in America and Switzerland in the construction of large tunnels by modern machinery, it is now believed that the capital outlay originally estimated could be considerably reduced, making the scheme a commercial proposition.

CONTRACTORS FOR WORK ON ASSUAN HYDRO-ELECTRIC SCHEME

MAIN AND HOUSE TURBINES—Escher Wyss Engineering Works Ltd., Zurich; Ateliers des Charmilles, Geneva; and Karlstad Mekaniska Werkstad, Karlstad.

MAIN AND HOUSE ALTERNATORS—A.S.E.A., Vasteras, Sweden; Brown Boveri and Company, Baden; Oerlikon Ltd., Zurich; and S.A. des Ateliers de Secheron, Geneva.

TRANSFORMERS—A.S.E.A., Vasteras, Sweden. SUDD CONTRACT—Societe de Construction des Batignolles, France.

DIESEL ALTERNATOR SETS AND SWITCHGEAR—Thos. Cook & Son Ltd., and Yassin Engineering Co., Cairo.

Civil Engineering Aspects

By ROLT HAMMOND, A.M.I.C.E. Methods of foundation exploration; Design and erection of large penstocks; problems of Water-hammer and other aspects of hydro-electric civil engineering.

La mise en valeur de la houille blanche demande presque toujours une dépense considérable de capital dans les ouvrages de génie civil. L'auteur montre ainsi la nécessité d'études approfondies et de devis comparatifs dans la recherche des meilleures solutions aux multiples problèmes posés. Il souligne qu'il est important de connaitre la nature de la couche qui recouvre la base rocheuse; le contour de la surface rocheuse, la perméabilité de la roche et des apports et la direction du ruissellement souterrain. Il cite ses auteurs et il décrit les méthodes d'exploration de la base rocheuse ainsi que d'autres problèmes qui peuvent intéresser l'ingénieur civil.

A causa del hecho que el desarrollo de casi toda la fuerza hidráulica significa el desembolso de grandes capitales en efectivo debido á los trabajos esenciales de ingenieria civil el autor demuestra que las mejores soluciones pueden ser resueltas á fuerza de estudios cuidados y cálculos comparativos, y subraya la importancia de averiguar el tipo del material que cubre la base roquera, el contorno de la superficie roqueña, la permeabilidad de la roca y otras formaciones, así como tambien el curso de corrientes subterraneos. Se citan las autoridades interesadas y se describen los metodos de la exploración del subsuelo, así como tambien otros problemas que sean de interés al ingeniero civil.

NEARLY every water power development involves large capital expenditure on civil engineering works; it is wise, therefore, to devote a great deal of thought and care to the overall planning and design of a hydro-electric scheme. A careful and accurate preliminary survey will ensure at least that the project is based on balanced judgment and a correct appraisement of true conditions on site.

In general the most favourable position is one which provides minimum cost of development per unit of power, and minimum unproductive period of construction; the latter being of the greater interest and concern to the civil engineer. Other important determining factors are that the amount of power developed shall be as nearly as possible equal to the demand; that the transmission line shall be completely reliable in operation and reasonable in first cost; that records of river and stream flow shall be accurate; and that there shall be ample opportunity for future expansion. There must also be reasonable access to the site for transport of heavy machinery and equipment. The engineer is thus faced with a tremendous responsibility in reaching a firm decision on the best site to be chosen for a power station, because a mistake in the beginning may well entail heavy capital expenditure for many years ahead. In some cases, for example, there may be many alternative solutions to the problem of how best to develop the latent water power resources of any particular district. The best solution can only be determined by careful studies and comparative estimates—work in which air survey can now provide a powerful aid throughout the whole development of a water power scheme.

Having selected his site, the engineer must carry out a complete investigation, with particular emphasis on all difficulties likely to be encountered in foundation work. Until comparatively recently foundations were designed largely on empirical lines, whereas to-day they can be planned on a scientific basis, backed by the now standard tests of soil mechanics, supplemented by detailed knowledge of the strength and permeability of the strata underlying the foundation. Some of the methods used to provide geological information required for the design of hydro-electric schemes have been reviewed by V. D. Harty (" *Site Investigations for Reservoirs and Dams," by V. D. Harty, B.A., B.A.I., A.M.I.C.E.—Trans.Inst.C.E. Ireland—Vol. 72, 1946*).

Rock Structure Tests

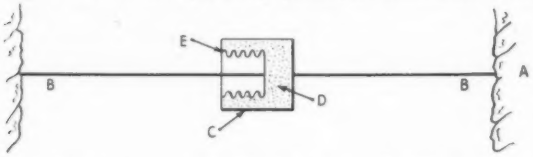
The main objectives will be to provide information on the type of material overlying the rock; contour of the rock surface; permeability of rock and of drift; course of underground streams and seepage; effect of river water on the proposed structures, and materials available for earth dams and their properties. Harty gives some very useful advice on the testing of rock for leakage, and recommends that such tests should be carried out in descending stages of 20 feet. For the first stage, water pressure should be 90 lbs. per sq. in. and up to 150 lbs. per sq. in. for subsequent stages maintained for ten minutes. In this connection Professor Lugeon (" *Barrages et Geologie* ") states that for dams less than 30 metres high a leakage of 3 litres per lineal metre per minute is reasonable (0.21 gallons per foot per minute) and for dams above this height he gives a figure of one litre per lineal metre per minute.

In a recent paper, Dr. P. W. Seewer (" *Recent Tendencies and Present Position of Hydraulic Machinery—Water Power Plant,*" by *P. W. Seewer, D.E., M.I.Mech.E., — Proc.Inst.Mech.E., Vol. 157, 1947*) drew attention to the fact that some hydro-electric power plants are completely or partially arranged underground. He referred to Kangrede, Sweden, which contains three reaction-type generating sets of 52,000 brake horsepower operating on a head of 58 metres at 167 r.p.m., each turbine absorbing 2,460 cubic feet of water a second. This plant is entirely underground, and it is claimed that such a

power station is strategically the safest possible; that it is perfectly protected against rock, earth and snow avalanches; is better sheltered against climatic extremes; allows greater head to be utilized in a river; is no more expensive than a surface plant if the rock is sound and, last but by no means least, that there is little or no interference with local amenities.

All this strongly emphasises the need for thorough investigation of the rock structure at any proposed site, and lends considerable interest to a measuring equipment developed by Sulzer Brothers for determining stability, elasticity, strength under water pressure, and permeability of natural rock (" *Equipment for Measuring Gallery Expansion and Determining the Elasticity of Rock*"—*Sulzer Technical Review, No. 3/4, 1947*). To-day it is generally accepted that only hydraulic pressure tests in rock chambers can provide adequate information as to the permeability and strength of the rock formation. Such tests obviously reveal mechanical properties of the geological structure as a whole, whereas mechanical pressure tests on rock specimens are inevitably local, applying only to isolated sections of rock.

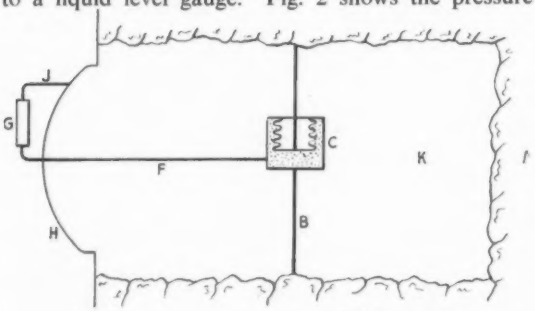
When a pressure shaft in the rock was being projected for the distribution plant of the Hauterive Power Station of the Rossens hydro-electric scheme, the contractors suggested that a method should be found for measuring the expansion of the galleries under the influence of internal water pressure. Sulzer Brothers studied this problem and proposed a simple hydraulic system which has given excellent results in practice, and which has been patented by the firm. Fig. 1 shows its operating principle: extension rods



A Rock *C* Measuring cup *E* Spring bellows
B Extension rod *D* Sealing liquid

Fig. 1. — Operating principle of the rock pressure measuring device

B, B are firmly attached to the rock A of the gallery and all radial deformations are transmitted to the yielding spring bellows E. The latter is filled with sealing liquid D and has a measuring cup C. Any radial deformation of the rock is transmitted by rods B, B to the yielding spring bellows and from the latter to a liquid level gauge. Fig. 2 shows the pressure



A Rock *G* Liquid gauge
B Extension rod *H* Sealing cover
C Measuring cup *J* Pressure compensation
F Connecting pipe *K* Test chamber

Fig. 2.—Pressure compensating device for the rock pressure device

compensating device employed; the top end J of the liquid level gauge G is connected to the water space of the test chamber. To enable the level to be read in the gauge, the measuring cup C is filled with a coloured sealing liquid of high specific gravity which does not mix with water.

Layout of the penstocks at the Rossens power station is shown in Fig. 3, which also indicates in thick

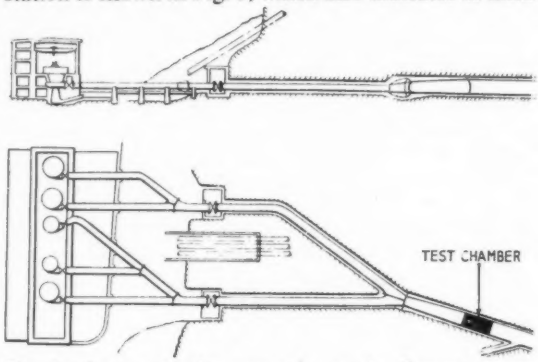
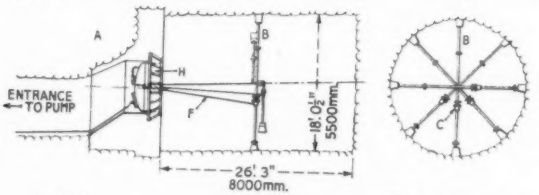


Fig. 3.—Layout of the penstocks at the Rossens power station, showing the position of the four rock testing equipments in solid black

black the position of the four rock testing sets used. The equipment was subjected to calibration and preliminary tests, in the course of which it was confirmed that indications of the level gauge were a linear function of the expansion of the spring bellows. One of the rods B was firmly anchored, while the other could be tightened or slacked off by set screws. Expansion of the spring bellows should then be measured with a dial caliper gauge and allocated to a certain liquid level. Calibration was carried out in a closed space under liquid pressure; the measuring equipment was installed in a high-pressure container which could be submitted to test pressures up to about 230 lbs. per sq. in.

A sketch of the actual test chamber is shown in Fig. 4, the entrance being closed by a sealing cover



A Rock *C* Measuring cup *H* Sealing cover
B Extension rod *F* Connecting pipe

Fig. 4.—Test chamber for rock pressure measurements on the bank of the River Saane near Hauterive

H: the chamber was hewn out of the Molasse rock on the banks of the River Saane near Hauterive, where the pressure shaft of the new Rossens power station was to be sunk. The measuring equipment had to be installed with the greatest care to ensure that all air was evacuated and all connections absolutely tight.

Water Losses

Extremely interesting and valuable results were obtained. Expansion in the vertical direction was greater than in the horizontal direction, a fact confirmed by mechanical pressure tests and being due to geological stratification. Modulus of elasticity of the rock was about 60,000 kgs. per sq. cm. hori-

zontally and 40,000 kgs. per sq. cm. vertically. Elasticity increased with rising internal pressure because of increasing humidity of the rock. Creep and similar time phenomena were observed, those being largely dependent upon the moisture content of the rock; and there was a distinct relationship between water losses, expansion and elasticity.

Initial tests in the naked rock showed that water losses rose in almost linear relationship to pressure. In the creep test, at constant pressure a gradual balancing of water losses and expansion was recorded, the figures approaching a limiting value. Percentage water losses and rock expansion figures decreased with increasing pressure, and its favourable behaviour was extremely important and significant. A second series of tests was carried out in the chamber after it had been lined with partly reinforced concrete, and after the surrounding strata had been grouted. It was found that under high water pressure the concrete cracked in spite of its reinforcement, and in that state was not capable of preventing either water loss or expansion to any great extent.

The Ingersoll Rand Calyx core drill is now widely employed for foundation exploration. Fig. 5 shows its

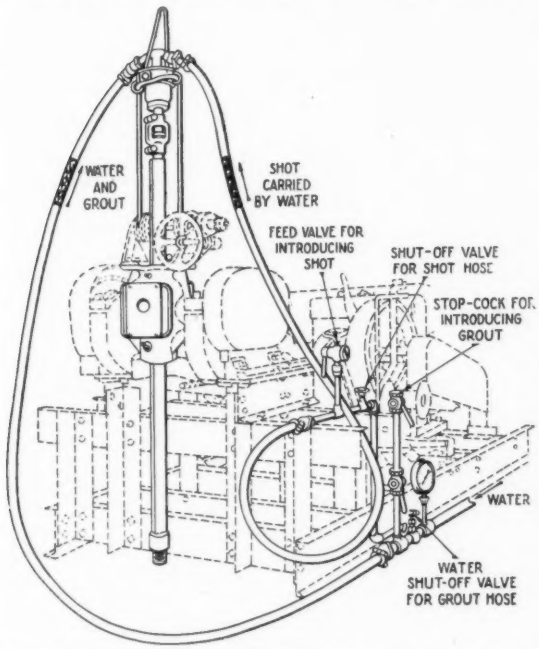

WATER AND GROUT
SHOT CARRIED BY WATER
FEED VALVE FOR INTRODUCING SHOT
SHUT-OFF VALVE FOR SHOT HOSE
STOP-COCK FOR INTRODUCING GROUT
WATER
WATER SHUT-OFF VALVE FOR GROUT HOSE

Fig. 5.—Sketch showing the operating principle of the Ingersoll Rand Calyx core drill

operating principle; steel shot, crushed to form the cutting abrasive, is introduced into the wash water while the bit is drilling through the ground. After a length of core has been bored, the flow of shot is shut off and grout is introduced to break off the section inside the bit.

With this type of drill the engineer can test the rock formation underlying the site of a dam for strength, soundness and general suitability as a foundation material; if used in combination with the Sulzer rock testing apparatus already described, we can obtain a complete picture of geological conditions *in situ*. A recent outstanding example of the use of this core drill was on the construction of the Warragamba Dam on the Nepean River, New South Wales; here a total depth of 2,570 feet of 48-inch diameter holes was sunk in exploring the sandstone strata beneath the foundation. The dam itself will be 340 feet high, of the gravity type, and the reservoir will impound 450 million gallons of water. For this particular site exploration the drill bit was turned by a 5½ inch square spindle, the bit being kept central in the borehole by three radial arms set at 120 degrees to one another and spaced at intervals of 40 feet.

The most important feature of the Calyx drill is its ability to sink holes of large diameter to a considerable depth. It is primarily a rock drill and is not intended for cutting through overburden or formations which are softer than the bit itself. With a 48-inch diameter bit it is possible to cut limestone at 15 to 18 inches an hour, or granite at 10 to 12 inches an hour.

The engineers responsible for the construction of the Norris Dam, a structure erected by the Tennessee Valley Authority, decided that core drills of small diameter often gave unreliable results. They therefore carried out underground exploration by means of 36-inch diameter holes cut by a Calyx rock drill, the actual strata being examined *in situ* by a man lowered down the hole. Results were so satisfactory that a similar procedure was adopted for the Grand Coulee, Fort Peck, Bonneville, Shasta, Friant and other large dams. This rock drill has been adopted as standard by the U.S. Bureau of Reclamation and by the U.S. Army Engineers.

Problems of Water-Hammer

Design and erection of large penstocks present many difficult and sometimes costly problems to the civil engineer. Billings (" *Water-Power in Brazil, with Special Reference to the Sao Paulo Development" by A. W. K. Billings, M.I.C.E.—Inst.C.E. Special Meeting, 16/6/36*) has pointed out that the cost of a pipe line, relatively insignificant in a low-head plant, is in a high-head plant about equal to that of the corresponding turbine, generator, transformer, auxiliaries and switching apparatus combined. He also emphasises the fact that an accident to a high-head pipe line may be extremely costly, endangering life and property and disrupting important public services for a long time. In Brazil great precautions were taken to prevent slides, and the concrete anchor blocks on the Serra project weigh from 1,000 to 3,200 tons each; total volume of concrete required for them as well as for the piers of the three pipe lines amounts to 25,000 cubic yards.

The problem of water-hammer in penstocks has been closely studied for some years, and recently Dr. Charles Jaeger, D.Sc., gave an extremely interesting and valuable review of the subject (" *Water-Hammer Effects in Power Conduits: Accidents due to Water Hammer."—Journal Inst.C.E., February, 1948)* in which he referred to the effects of vibration, resonance and auto-oscillation. He pointed out that the most frequent cause of resonance in pressure pipes was hunting of the turbine governor, but he also referred to a very important type of resonance discovered and first fully calculated by Rocard in connection with the Lac Blanc-Lac Noir accident of 1934. According to Rocard, the elastic mechanical parts and the liquid mass of a hydraulic plant formed a complete oscillating system which could be set in vibration by any fortuitous impulse. He calculated that the movable

Fig. 6.—Fusarc automatic arc welder laying down joint on 8-foot length of penstock for the Loch Sloy scheme

guide vanes of the huge centrifugal pumps of Lac Noir formed, with the water-column, such a system and the vibration set up in it might explain the failure of the pipe.

Jaeger writes that resonance in pipes, especially in the form of auto-oscillation, can present grave dangers, but it is less well known that resonance also presents a serious threat to the pressure gallery above a surge tank, and may even damage it. He also points out that the theory of harmonics shows that, even if the surge tank is well designed, the harmonics may be transmitted to the upstream side. He investigated a case where cracks had developed three times in a certain tunnel, each time at the same place; they were parallel and horizontal, more than 60 feet long, which indicated severe water-hammer. Resonance due to auto-oscillation was suspected, and a further examination revealed more cracks at equal distances from one another, further study showing that resonance of the eleventh harmonic had occurred inside the tunnel. According to Rocard's theory of auto-oscillation, such resonance must have been due to an oscillating member in the system. It was finally traced to an old air-valve fitted with an oil dashpot. Indeed, there is still much to be learned in this branch of engineering.

Efficiency by Welding

Large welded penstocks have become very popular in recent years, those constructed for the Boulder Dam being amongst the most outstanding. P. J. Bier (*"Arc Welded Power Penstocks" by P. J. Bier—Prize Paper, Lincoln Arc Welding Foundation, 1943*) has described in detail the welded penstocks of the Shasta Dam on the Central Valley Project, California. These are claimed to be the first of such diameter and plate thickness with all joints double butt welded, and radiographed, with every 20-foot pipe section stress relieved and tested under water pressure. Moreover, the whole installation was subjected to a hydrostatic pressure test equal to 150 per cent. of the operating pressure. This proved its safety under the most severe operating conditions.

The five penstocks serve turbines with an individual output of 103,000 horsepower at 330 feet head, with a full generator rating of 75,000 kilowatts at unity power factor. The penstocks vary in length from 798 to 931 feet, they are 15 feet in diameter, shell thickness varying from $\frac{3}{4}$ inch at the intake end to $2\frac{3}{8}$ inch at the turbines. All joints are double butt welded, except the field girth joints opposite the contraction joints in the dam.

These penstocks would have been too large for shipment when fully fabricated, so it was decided to prepare the plates for welding and to roll them into half circles; they were then fabricated at a special plant about a mile from the dam. In commenting on the design of penstocks, Bier has emphasised the necessity not only for ensuring structural safety but also for achieving the utmost possible hydraulic efficiency in order to reduce loss of head. The smooth interior of a welded penstock is greatly superior to its rivetted counterpart, and Bier points out that it can therefore be of smaller diameter and less costly. Total head loss was calculated for one penstock, it being 5.87 feet for rivetted construction against 3.59 feet for welded construction; and trial analysis proved that a rivetted penstock 16 ft. 9 in. in diameter would have the same capacity as a 15-foot diameter welded pipe. Total possible saving in cost by using welded construction was about 41.4 per cent. of the cost of rivetted construction.

Arc welding is being increasingly employed for the welding of penstocks, because the modern automatic welding plant is a thoroughly tried and dependable apparatus. Fig. 6 shows a Fusarc automatic welder laying down a welded joint on an 8-foot section of some 7,600 feet of steel penstock for the North of Scotland Hydro-Electric Board's Loch Sloy scheme. The diameter of this penstock varies from 7 feet to 7 ft. 6 in. and the shell thickness from $1\frac{1}{16}$ to $1\frac{9}{16}$ in.; weldable steel is used, in accordance with B.S.S. 15, its carbon content being restricted to less than 0.2 per cent. Tensile strength lies between the limits of 28 and 33 tons per sq. in. Each length of penstock was mounted on a roller jig as shown, the welding machine running along an overhead gantry.

When the first runs of welding are laid down, the back of the joint is supported by shaped carbon slips; thus the operator can safely burn right through the flat roots into the refractory material and this will ensure complete inter-penetration of the first two runs. Two runs of weld metal are laid down on each side, a Fusarc 2-gauge Seamec type of electrode being used, taking 840 amps for all passes. Welding speed is about 10.4 inches a minute and electrode consumption about 1.20 lbs. of metal a foot run for each pass. Each welded 24-foot length is joined in a continuous pipe on site by rivetted straps.

The author realizes that he has but touched the fringe of the civil engineering work involved by the development of a large-scale hydro-electric scheme; but he hopes that this review of some points of interest will serve to emphasize the vital importance of scientific planning at all stages of construction.

The Tongland Power Station of the Galloway Water Power Company containing three 11,000 kW "English Electric" water turbine-driven alternators

The Falls of Morar

Inauguration of Scottish Scheme

The North of Scotland Hydro-Electric Board put into operation the first of its hydro-electric stations on December 21. The projects are part of the board's first constructional scheme.

THERE is rejoicing in the remote parts of Scotland now that the first two stations of the North of Scotland Hydro-Electric Board's 102 projects are bringing cheap electricity to areas that had nothing better than oil lamps. Although the Morar and Lochalsh schemes are small, being intended mainly to meet purely local requirements, they represent the inauguration of the board's ambitious plan which will ultimately supply electricity to the grid system, and for that reason it has a special significance.

The Morar station is the first underground generating station to be built in Great Britain; while the Lochalsh project has created a new loch in the hills roughly 500 feet above Loch Alsh. The generating station building at Nostie Bridge, the first to be completed by the board, is of traditionally Scottish design. It has been built mostly of local hammer-dressed stone and has a low pitched roof covered with heavy slab slates.

The Loch Sloy project, which is due for completion next year—thus bringing reality to Constructional Scheme No. 1, provides for generating plant with a capacity of 130,000 kW, and an output of 100 million kWh in a year of normal rainfall. It may be possible to bring in an additional catchment area and so increase the output still further.

The Morar Project

The Morar project, which will serve 90 per cent. of the people in an area of roughly 71 square miles, at present has a limited plant capacity of 600 kilowatts; but the project covers an ultimate development of 2,000 kilowatts and the production of six million units of electricity annually. Loch Morar is 11 miles long and the deepest loch in Scotland. In order to obtain storage and to increase the head, the scheme provided for raising the level of the loch from 31 feet above ordnance datum to 40 feet O.D. Meantime the

level is being raised to 34 feet O.D. by means of an automatic regulating weir erected on concrete foundations in the river bed immediately above the Morar Falls.

The regulating weir is of special interest. Although this is a British invention and has been used abroad, notably in America, it is the first to be erected in this country. This type of weir or " drum-gate " is used to keep a steady water level and at the same time to prevent flooding. The Morar is narrow with a large loch behind it. In times of heavy rain the presence of a permanent structure such as a dam on the river bed would have caused considerable flooding of the surrounding land. The " drum-gate " regulating weir, however, adjusts itself automatically to the flow coming from the loch and when there is a flood is fully open and causes no obstruction. It is controlled by means of a valve which passes water into a chamber beneath the weir causing the gate to rise, as the level of water in the loch decreases and fall when the level in the loch rises.

Consultants for the project were: Messrs. J. & A. Leslie & Reid (civil engineering); Messrs. Merz & McLellan (electrical); and the architect was Dr. Reginald Fairlie, of Edinburgh. The contractors were: Whatlings Ltd. (civil engineering); Glenfield & Kennedy, drum-gate and sluice gates; Bruce Peebles Ltd., turbo-alternators; Boving & Co. Ltd., turbines; Bonar Long & Co. Ltd., transformers; Cooke & Ferguson, Ltd., 11 kV switchgear and associated equipment.

The Lochalsh project will supply an area stretching in the north from Applecross and Shieldaig in western Ross-shire, south to Glenelg and Arnisdale in western Inverness-shire and westwards into parts of the Island of Skye, including a widely dispersed population of about 7,500.

The Lochalsh Project

The work carried out included the construction, about one mile up Gleann Udalain, of a dam, 56 feet high and 250 feet long across the Allt Gleann Udalain, the erection of a pipeline 5,230 feet in length and the building of a generating station of 1,000 kW capacity about 70 yards south-east of Nostie Bridge. The project can be extended to an ultimate capacity of 4,000 kW with an estimated annual output of 7 million units. The plant operates under a maximum gross head of 478 feet. A pipeline, 5,230 feet long, leads the water from the dam to the generating station, which is built of local stone in the tradition of the neighbourhood. Every care has been taken to ensure matching with surroundings, even to the provision of a raised flower bed at one entrance to the building.

The station is situated east of Nostie Bridge, and owing to the absence of rock at a reasonable depth, and the unsatisfactory nature of the ground, a box of sheet steel piling has been formed to contain the whole of the foundation of the building; the main turbine blocks, discharge ducts and the by-pass chamber being constructed above the top of the box.

Two 21 inch Gilkes patent Turgo impulse turbines with a total output of 720 h.p. are installed; their

Dam across Allt Gleann Udalain, and valve house

normal running speed is 750 r.p.m., and at full load each machine passes 1,080 cubic feet of water a minute. Each turbine is coupled to a 500 kW alternator.

The consulting engineers for the civil engineering work were Sir William Halcrow & Partners, and for the plant and machinery, Messrs. Kennedy & Donkin. Mr. James Shearer of Dunfermline was the architect. The contractors for the project were: Richard Costain Ltd. (civil engineering); Messrs. Crompton Parkinson, switchgear and ancillary gear; Messrs. Gilbert Gilkes & Gordon, turbines; Messrs. Bruce Peebles, alternators; Messrs. Bonar Long & Co., transformers; and Messrs. Horseley Bridge and Thomas Piggott Ltd., pipeline. Sub-contractors for the constructional work at the generating station were Messrs. Alexander Walker of Skye; for the pipeline erection, Messrs. Lanarkshire Welding Co.; and Glenfield & Kennedy manufactured the valves.

Estimate of Potential Power

When approval was given to the full development scheme of the North of Scotland Hydro-Electric Board in 1944 it was expected that the 102 projects would have an aggregate output of 6,274 million kWh, but more recent estimates suggest that this figure is likely to be exceeded. As further surveys are carried out it is believed that the potential output for the whole of Scotland may be over 10,000 million kWh. The following table shows separately the kWh generated in 1944 from water in Scotland, England and Wales, and a recent estimate of the annual kWh that could be produced in the three countries in 1966.

Some sites may at present be too costly to equip and future development will be governed to some extent by the price of coal.

	kWh generated in 1944 Millions	Estimated kWh in 1966 Millions
Scotland	1,064	10,225
England	15	25
Wales	97	750
	1,176	11,000

On the assumption that the above estimate is reasonably accurate the full development of the water power resources of this country might save a further 6 million tons of coal *per annum*. The small remaining undeveloped sites in England may not all be available for producing electricity. Several have already been earmarked by water engineers as suitable sources of domestic supply and the prospects of combined power and water supply schemes are very limited.

The Severn Barrage

By Our Parliamentary Correspondent

DECISIONS on hydro-electric schemes in connexion with the Severn Barrage are postponed for at least two years according to replies by the Minister of Fuel and Power to Parliamentary questions in December.

Mrs. Middleton (Lab., Plymouth, Sutton) asked the Minister whether the inquiry by his Department into the practicability of the Severn Barrage scheme for hydro-electric production had yet been completed and what were the conclusions reached.

Mr. Hugh Gaitskell replied that the construction of a tidal model was an essential preliminary to further consideration of this project. The construction of this model and the conduct of the necessary experiments would be under the direction of the Hydraulics Research Board. Progress had been delayed owing to the pressure of more urgent work and the difficulty of finding an appropriate site, and it was unlikely that any final conclusion on this would be reached for some considerable time.

When he was further pressed by Mrs. Middleton to say how long it would take to get the advice of experts on the subject, Mr. Gaitskell said it would be at least two years before they reached any final conclusion.

Mr. Peter Freeman (Lab., Watford) asked " In view of the fact that these proposals vitally affect South Wales and the important development areas, and that the Severn Bridge scheme itself has been postponed, will the Minister consider taking further steps to hasten this report and inquiry in order that something practical may be done in this direction to assist these areas? "

Mr. Gaitskell said there was nothing further he could do to expedite the matter and added " I would point out that this project will cost at least £60 million and take eight years and therefore we should be careful about what we are doing before we start."

Mr. Berry (Lab., Woolwich), of the Metropolitan Water Board, asked whether the Minister had taken into account world-wide experience in hydro-electricity and whether he was aware that while we might not have advanced far in this country, quite a number of other countries had done a lot of research and practical work in this connexion. Mr. Gaitskell did not think that we had any shortage of experts in this country.

The outlook for other schemes is apparently even worse. Replying to another question from Mrs. Middleton about the consideration given to other schemes such as the utilisation of the race of the Menai Straits and of the Pentland Firth, the Minister said that the merits of further tidal power schemes could not be determined without detailed surveys and the construction of tidal models. Owing to the shortage of skilled staff and the difficulty of finding suitable sites it would not be possible to proceed with such work until the experiments with the Severn Barrage model had been completed.

Mrs. Middleton then wanted to know whether he had any intention of proceeding with the construction of a model when labour became available and the experts could give attention to the matter. But Mr. Gaitskell suggested that they had better wait and see the result of the Severn Barrage model first.

Developments of Intake Works and Surge Tanks

By DR. CHARLES JAEGER . . . Consideration is given to the evolution in design of water-intake and equalizing chambers during the last twenty years. Influence of model tests and new methods of calculating silting and erosion in channels; main modern types compared.

Evolution des types de prises d'eau et des chambres d'équilibre au cours des vingt dernières années. Influence des essais sur modeles et des nouvelles méthodes de calcul; principaux types modernes; discussion.

Evolución de los tipos de toma de agua y de las camaras de equilibrio durante los veinte ultimos años. Influenzia de las experiencias con modelos y de los nuevos metodos de cálculo; tipos modernos mas importantes; discusión.

THE evolution in the design of low head power plants and the general arrangement of works, as they have been influenced by the type of turbines employed in hydro-electric schemes, allow the possibility of gaining more power from a few very big sets, instead of the numerous small ones that had to be accommodated in the older developments. A particular aspect of the problem has been the development of intake works and surge tanks in recent years, and in this article we shall consider some of the factors that have shaped it.

In taking our examples from the latest Continental practice, we have been guided by the consideration that water power developments are more numerous there, and the associated problems more complex, than in Great Britain; and that information on the progress made on the Continent during the long years of war has been inaccessible to the English-speaking world. It is therefore not out of place in *Water Power* to make a part of that information available.

Intake Works and Weirs

One of the main problems in the design of the "usine barrage," or power-house dam, has always been the smooth intake of water to the power-house. It is obvious from the point of view of streamlining and head losses that the latest solution applied at Ryburg-Schwörstadt (Fig. 1), which embodies the improvements in design of large low head plants during the last fifteen years, is well in advance of its predecessors.

If the water is led to the power-house by a head race, similar problems have to be solved to avoid head losses and to prevent the entrance of sand and gravel into the channel. How engineers first tried to solve the problem is illustrated in Fig. 2, which shows the entrance of the head race at the Mittlere Isaarwerke (Germany). For the exclusion of gravel the level of the bed of the channel (RL 496.00 m) is higher than that of the river (RL 494 m), the sill so formed being a defence against gravel and sand. This solution with an entrance sill for the protection of the channel was, at the time, by no means new; it had previously been adopted for other plants such as Olten-Goesgen (Switzerland). What is new is the idea of the small scour ways under the sill for preventing the deposition of sand and gravel in front of it, and permitting it to be cleaned "automatically". We cannot say if this arrangement proved very successful; certainly we are not aware of any other plant where it has been adopted.

A classical water intake on a mountain river some years ago is seen in Figs. 3 and 4. Here the entrance sill at level 1177 m. or 1179 m. is protected by a scour way (RL 1175) with sluice at the downstream end. The level of the river bed is at RL 1177. The main idea of this design, which has been repeatedly carried out in many places, is to prevent the entrance of sand and gravel into the head race during floods by opening the scour sluice; the sand and gravel is then supposed not to enter the head race but to be carried down the river. When the floods subside the scour sluice is closed and the water is then passed through a sand eliminator for the purpose of being cleared of sand and silt. It is known that in service there is always some trouble with this classical arrangement of intake works. Model tests have shown the way to a new and entirely different solution.

New ideas have been applied to the intake works of Moerel (Fig. 5), where the main feature of the intake is a longitudinal wall, in line with the river flow and separating the water entering the intake from the water passing the weir. The downstream sluice nearest the intake is normally closed; it is opened only under emergency conditions, when very large floods are discharged at the weir, the opened channel then acting also as a scour. Model tests have shown that when this arrangement is under working conditions with the sluice closed only small quantities of sand and gravel can enter the intake. The explanation is that when the downstream sluice at the end of the scour channel is closed the kinetic head $v^2/2g$ is partly recuperated, so

that the water level is higher at the sluice than at the upstream end of the longitudinal wall, thus causing a counter-current to flow along the bed and oppose the movement of gravel and sand into the scour channel. There is, however, the tendency to produce deep erosion at the upstream end of the longitudinal wall, so that provision has to be made to safeguard the foundations.

The same solution, first proposed for mountain rivers by the Hydraulic Laboratory of the Polytechnical School of Zürich, may be applied to the intake works of large rivers, and to the repair of older intakes as shown in Fig. 6, which refers to the Beznau Power Development. The maximum discharge in the head race had to be increased from 420 m³/sec. to 570 m³/sec. and measures were taken to prevent the increase of silt in the channel. Model tests were made first with a mixture of natural fine sands and later with coal dust and the results are shown in Fig. 6. The actual flood flow of the river may reach 2200 m³/sec. Similar tests were carried out for the Felsenau Power Development where the discharge to the head race was increased from 40 m³/sec. to 80 m³/sec.

In seasons when the discharge of a river is low there is no transportation of materials forming the river bed. Transportation begins at medium discharges, and it is then possible for the flow of water in the head race to be nearly equal to the momentary discharge of the river. In the presence of this condition there is no system capable of excluding solid matter from the head race, but the amount is of no great importance. Transportation increases in proportion to the river flow, but enough water is discharged at the sluices in the weir to divert solid matter from the intake, and it is when this takes place that the new arrangement works efficiently.

The design of intake works is closely related to that of weirs. A first design can be made on the basis of hydraulic calculations, but in most cases model tests are desirable. Several problems must be solved before the design can proceed. The first concerns the flow of water through the open weir. The water levels above and below the weir and at the intake must be calculated (or determined from model tests) for given rates of flow in river and head race. The calculations can be made by applying the equations of momentum and energy.

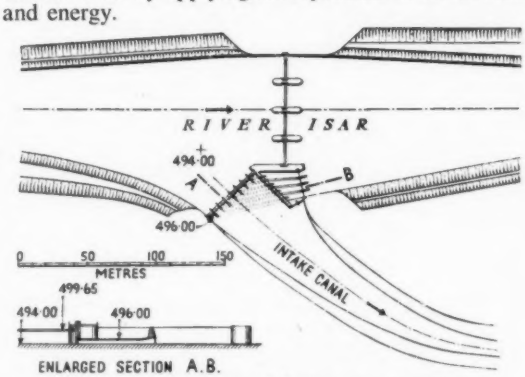
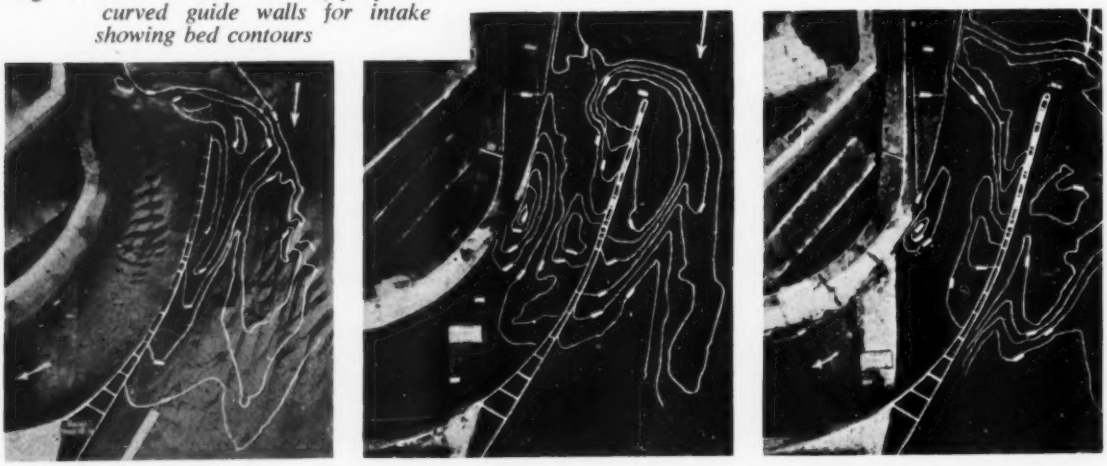


Fig. 2. *Intake at Mittlere Isaarwerke*

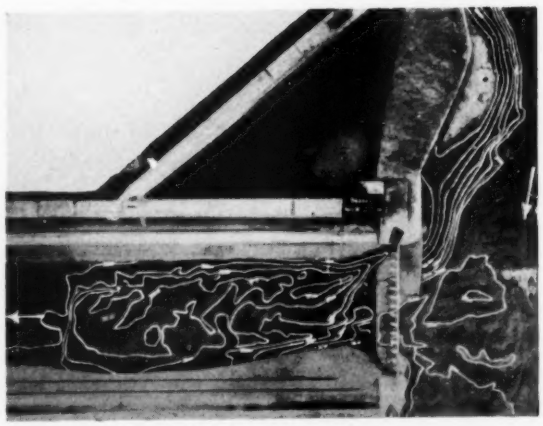
Fig. 6. *Beznau: Model tests of proposed curved guide walls for intake showing bed contours*



A. *Fine sand*

B. *Coal dust*

C. *Coal dust under max. flow. (2,200 cu. metres/sec in prototype)*



D. *Present intake showing entry of sand after long run with flow exceeding 1,300 cu. metres/sec prototype*

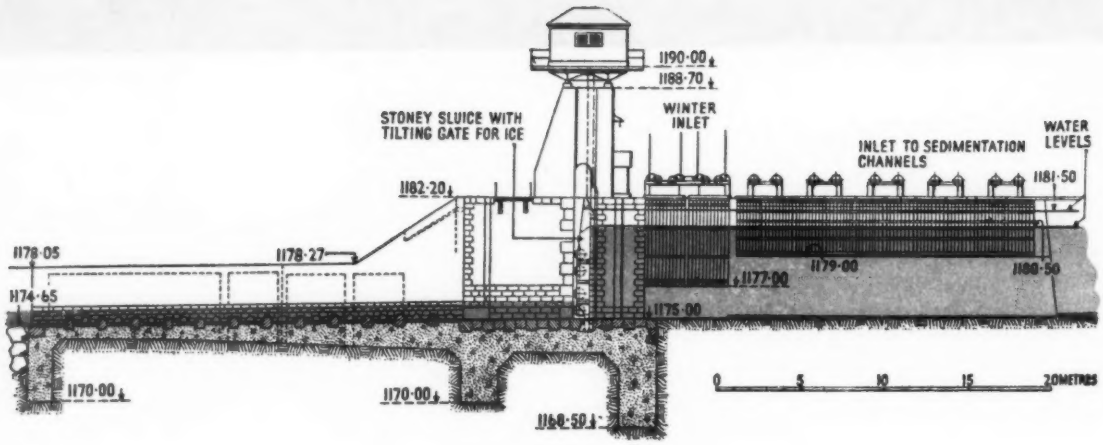


Fig. 4. Klosters Weir : Cross section of stoney gate

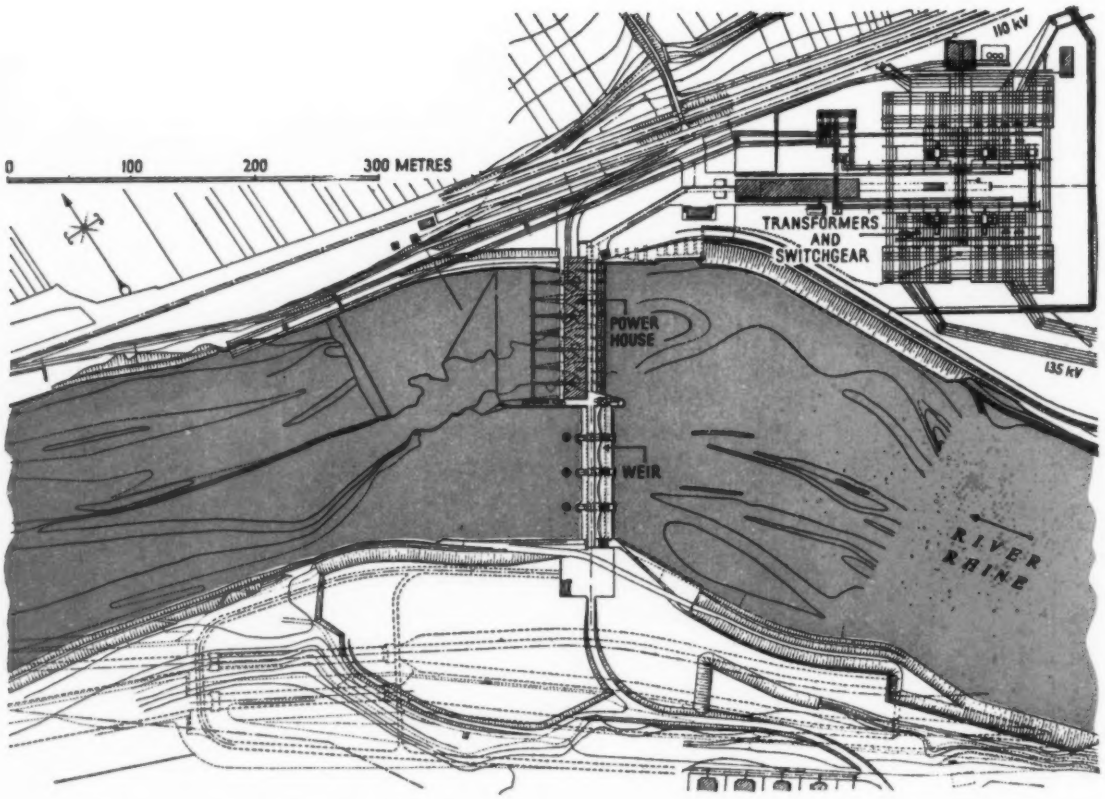


Fig. 1. Rybourg-Schworstadt : Plan of general layout

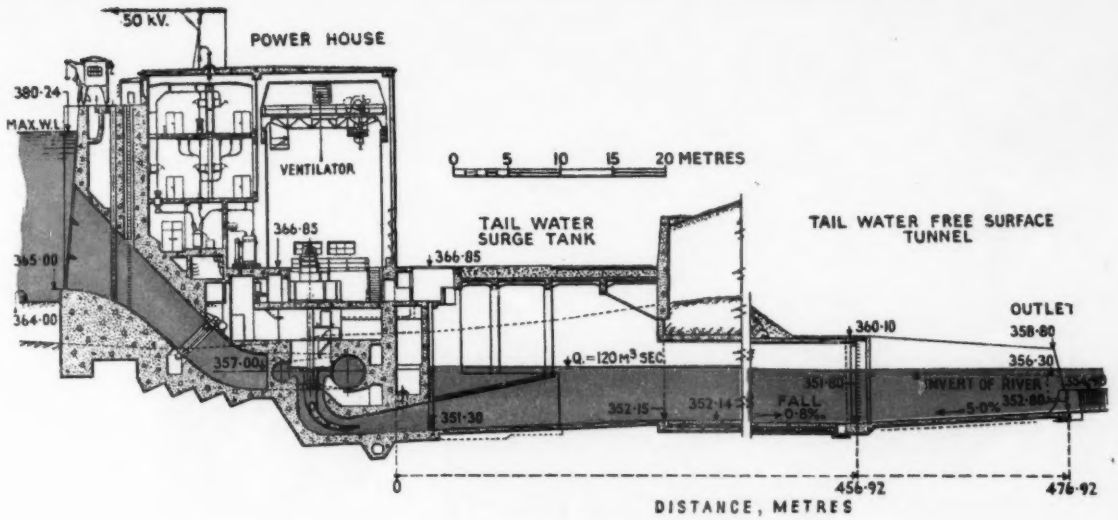


Fig. 15. Wettingen : Cross section of power house

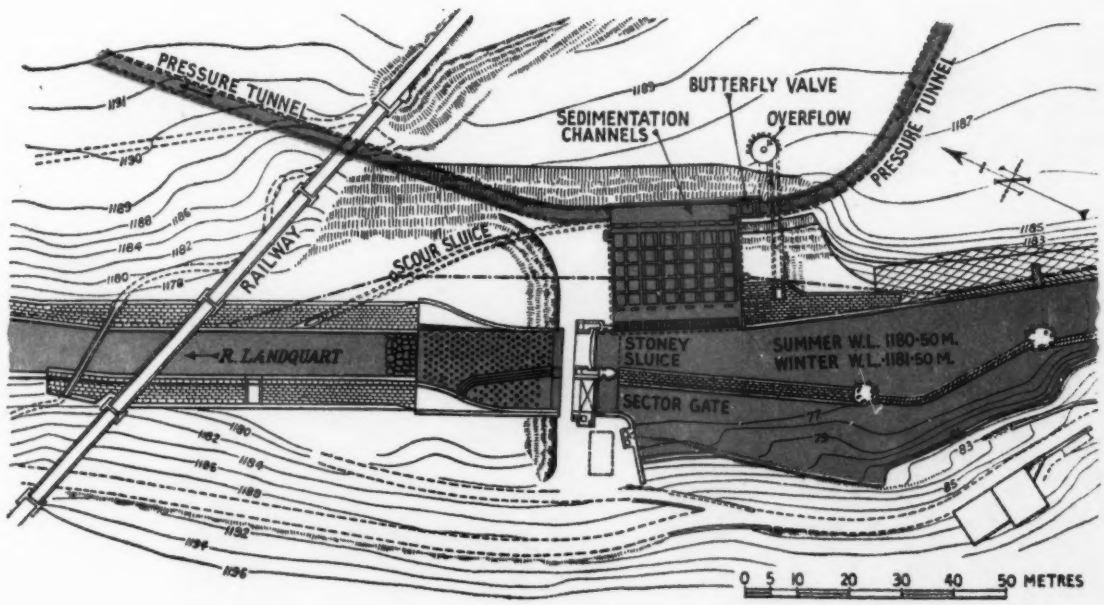


Fig. 3. Klosters : Intake and general arrangement

Folding plate specially prepared by
"WATER POWER" from material
supplied by Dr. Chas. Jaeger

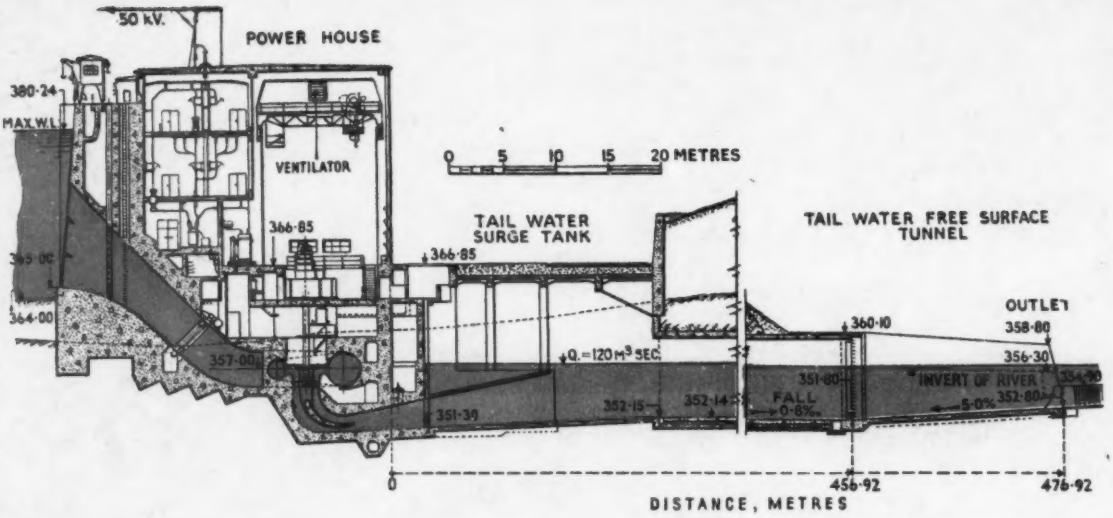
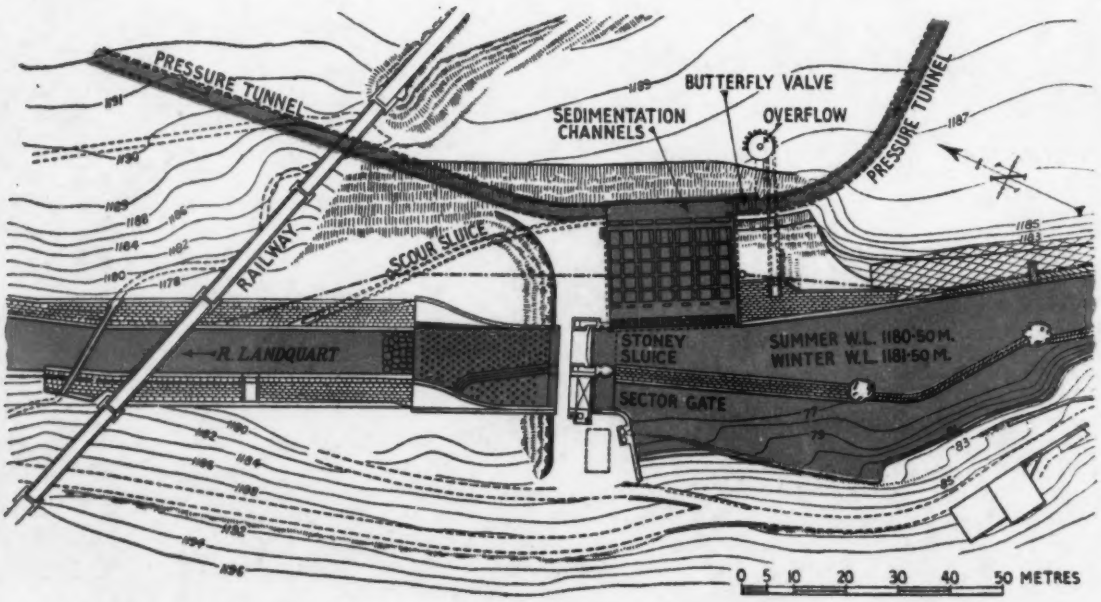


Fig. 15. Wettingen : Cross section of power house



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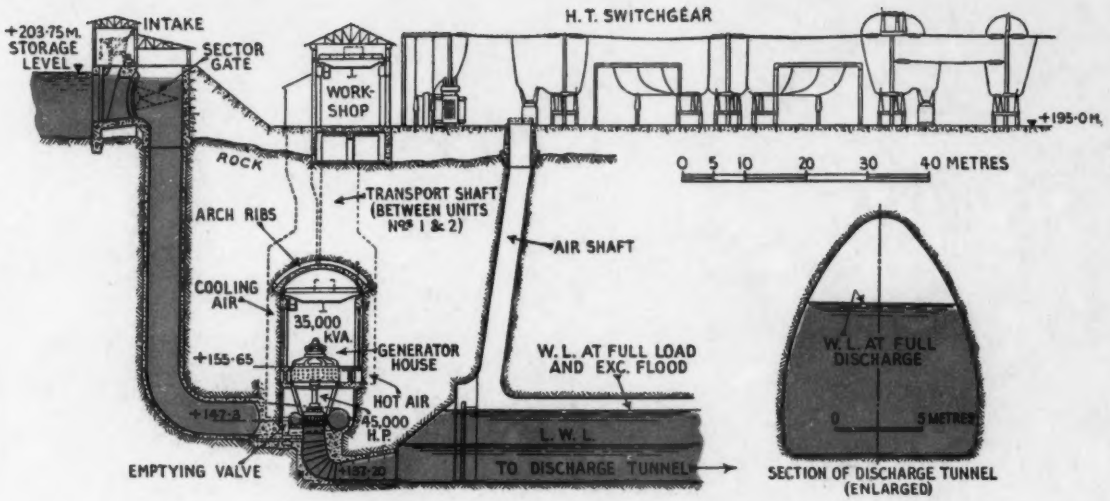


Fig. 16. Krangede Dam : Section of intake and turbo generator

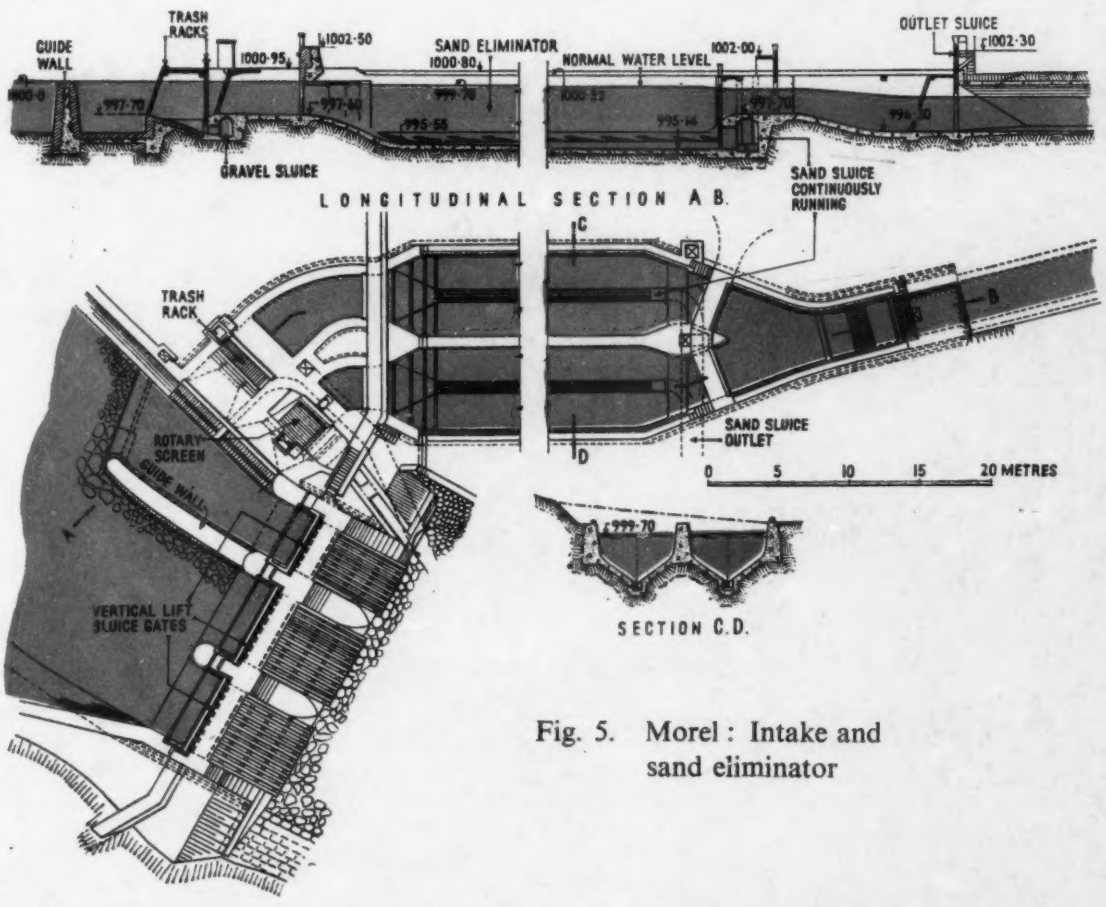


Fig. 5. Morel : Intake and sand eliminator

Two entirely distinct solutions can be obtained, depending on whether the roots of the equation of momentum are positive and real or imaginary. If they are real, the flow through the weir is always streaming and the water level upstream from the weir can be calculated as a function of the downstream level and the discharge. If the roots of the equation are imaginary it can be shown that the energy at disposal downstream is not enough for the discharge. Somewhere

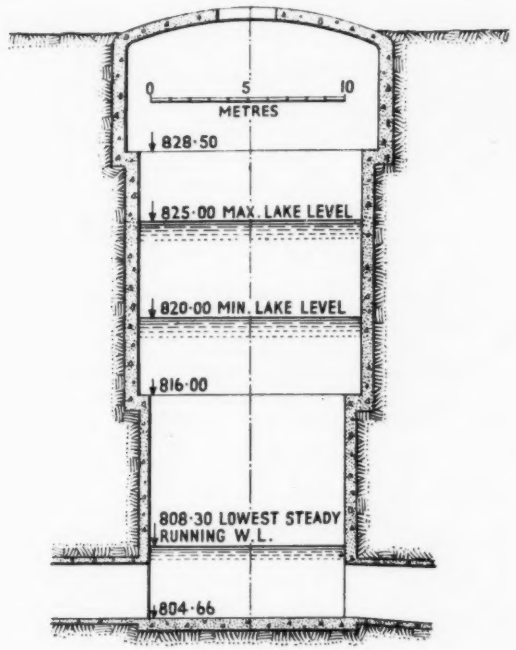


Fig. 7. *Albula surge tank*

below the weir the water will be at the critical depth, the flow changing from the streaming to the shooting règime and then back to the streaming règime, with the formation of a hydraulic jump in between. In this case the calculations have to start again from the point of the critical depth.

The relative widths of the intake and the weir can also be roughly calculated by means of the equation of momentum in conjunction with the theorem of energy. Other problems to be solved concern the silting of the river upstream from the weir and the erosion downstream. If we suppose that before the construction of the weir the river bed is stable, that is, without silting or erosion; and if we suppose further that we can regulate the sluice to avoid a back-water action at the onset of flood conditions with appreciable transportation of solids, then there will be no change in the river bed after the weir is built. But such ideal conditions are uncommon and very often the possibility of erosion or silting must be considered. The modern methods of calculation for transportation of solids are accurate enough for an approach to the problem, but in general model tests are unavoidable. The same can be said about the problem of erosion below the dam. The modern theory of erosion shows that four different types may be expected, and we know the conditions for their occurrence; but here again, model tests only can give an accurate answer to the question of danger from erosion.

As a result of this short survey, it is evident that very important improvements can be made in the design of intake works and weirs. Experiments and calculations can be used together to discover a satisfactory solution for any particular case.

Stability of Surges

With the technical and theoretical development of the surge tank it became evident that, for medium head plants utilising large volumes of water, the problem of stability of surges was the most difficult to solve. We shall summarize here the evolution of design of surge tanks and show how some difficult problems have been solved for modern schemes.

It is obvious that before 1904, or even 1910, the action of the surge tank was not well understood. The

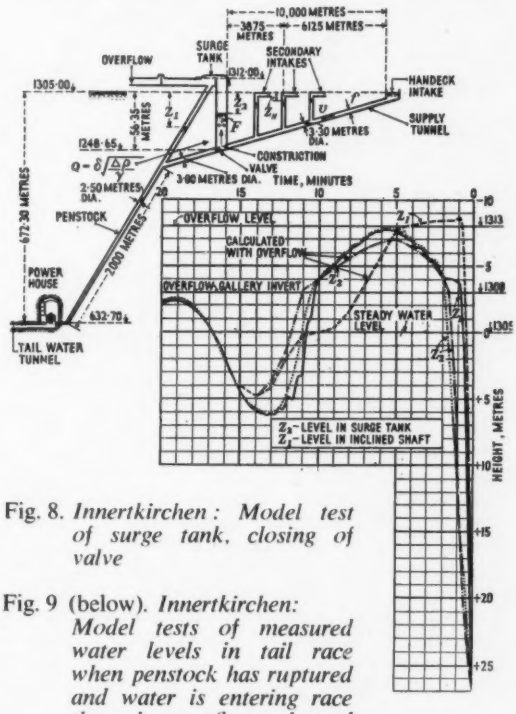
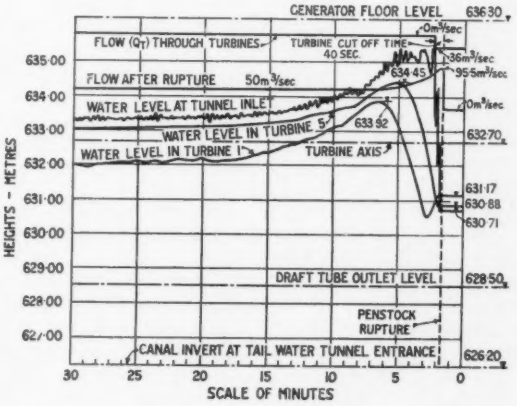


Fig. 8. *Innertkirchen: Model test of surge tank, closing of valve*

Fig. 9 (below). *Innertkirchen: Model tests of measured water levels in tail race when penstock has ruptured and water is entering race through overflow channel*



oldest European high head water power developments, in Austria and Switzerland, comprised head race channels or head race tunnels running free; the surge tank acting only as a reservoir capable of providing enough water for loading the machines. The theory and practice of surge tanks was established on a sound basis in the year 1908. The surge tanks of Albula (Fig. 7) and Löntsch are classical examples of the application of the newly established theory and contain all the essential features of later developments. The basis of this theory was enlarged in 1910 by the thesis of D. Thoma on the stability of small oscillations in surge tanks, and in 1915 R. D. Johnson explained the value of the differential surge tank.

Since then the complete theory of surges has been elaborated, including the theory of stability of large oscillations and of tank systems, and new features have been added to those already known. We must mention among new types of surge tanks that developed by Dr. Kaech, which is an extension of the Johnson type, the riser being external to the tank. The amplitude of surges in the main tank is reduced by a restricted orifice through which the water has to pass. The external riser is inclined and can be used during the construction of the steel-lined, sloping pressure tunnel, the new type of surge tank becoming a feature of a new type of power station. This type of surge tank is intimately connected with the modern technique of building penstock and power house entirely in the rock.

Among the first of the large underground power stations to be constructed was that of the Truyère in the Massif Central of France, followed shortly afterwards by the Innertkirchen Station of the Oberhasliwerke, in Switzerland. It is worth noting that when the power house of Innertkirchen was designed there was no thought of war, and the arguments in favour of this type of station were not military but purely economic. At that time, it was decided that an arrangement of works with penstock and power station entirely in the rock was safer than any other arrangement from the technical point of view, and not more expensive. Military considerations only came later. Both from the point of view of maximum surges and of security under working conditions the arrangement of Innertkirchen was submitted to extensive calculations and model tests.

The maximum and minimum surges in the tank were calculated and then tested on a model for the complete instantaneous opening and closing of the turbine needles, and also for successive opening and closing movements (see Fig. 8). Such oscillations could occur if the transmission lines between Innertkirchen and

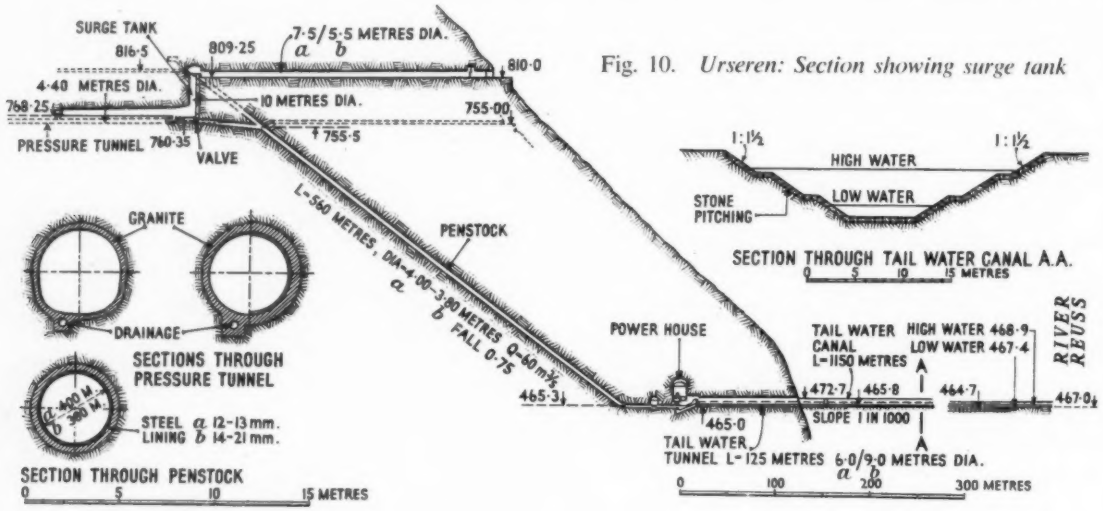


Fig. 10. *Urseren: Section showing surge tank*

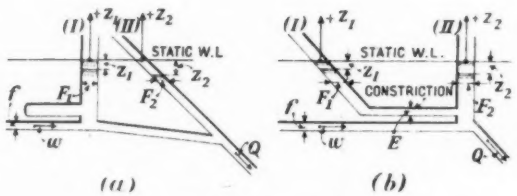


Fig. 11. *Surge tanks with two shafts*

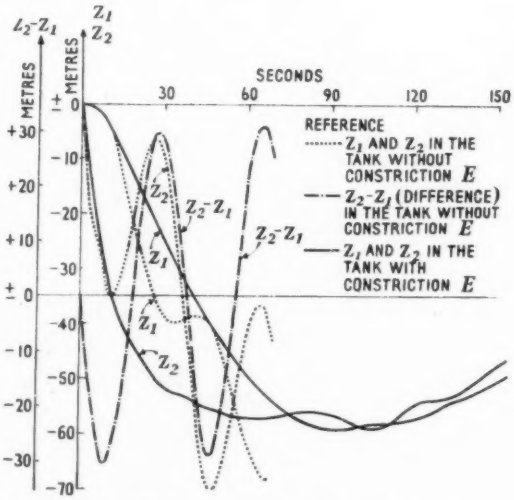

SECONDS
30 60 90 120 150
METRES
REFERENCE
Z1 AND Z2 IN THE TANK WITHOUT CONSTRICTION E
Z2-Z1 (DIFFERENCE) IN THE TANK WITHOUT CONSTRICTION E
Z1 AND Z2 IN THE TANK WITH CONSTRICTION E

Fig. 12. *Oscillations in surge tanks with two shafts*

some other big stations of the Swiss power distribution system were damaged.

In emergency cases, for example the rupture of the penstock near the rotary valve, either the butterfly valve at the bottom of the vertical surge tank or the rotary valves immediately upstream from the power station would close. Extensive calculations and tests were made:

a.—to determine the safe time for closing the butterfly and rotary valves, to avert dangerous surges in the pressure tunnel;

b.—to determine the torques exerted on the butterfly and rotary valves;

c.—to verify that in the most dangerous cases of emergency the generators would never be submerged even if, after a break at the penstock or valves, the power station were partly flooded.

Model tests were made in connection with the flooding of the power station and for investigating the conditions of flow in the tailrace (Fig. 9).

In particular cases where large volumes of water have to be controlled, or older arrangements of works enlarged, it may be necessary to provide a system of surge tanks; but as soon as more complicated systems are considered, the problems of stability of oscillations become more intricate. A first possibility for the improvement of an old surge tank is to connect the old power station with a new one electrically. In one instance a surge tank had been built large enough for the total closure of the needles of eight old turbines. The area of the surge tank was large enough to ensure stability of oscillation, but the volume proved insufficient when all the turbines were opened in a very short time. The result was that negative water hammer in conjunction with a low water level in the tank produced a dangerous vacuum in the pipe line which consequently broke. After the pipe line was repaired the surge conditions were partly improved by building a large reservoir chamber; but even then the surge tank proved insufficient. As it had previously been decided to make a second hydropower development near the first, advantage was taken to provide it with a very large surge tank with the intention that load changes should in future be taken by the new power station. This is an example of surge tanks working together with only electrical connections.

Because of the needs of engineering practice a theory of oscillation in surge tank systems with hydraulically connected shafts has been developed. Analytical methods give an idea of the complicated system of interference by the surges produced in one tank with the surges in another. Interesting types of surge tanks are illustrated in Fig. 10, showing Erstfeld of the projected Urseren Werke, and in Fig. 11. Curves of oscillation for the tank shown in Fig. 11b are reproduced in Fig. 12, and it must be obvious that the problem of stability of surges was a difficult one to be solved. Unstable secondary oscillations between the main vertical shaft and the secondary inclined shaft (Fig. 11b) could, however, be avoided by introducing a restricted orifice in the horizontal gallery uniting both shafts.

In the case where the two shafts are directly connected with the main pressure tunnel, shown in Fig. 11a, the problem of stability is easier, but there are sometimes reasons why this easier solution cannot be used; for example when a secondary source of water is introduced at the surge tank at Pfaffensprung.

The case represented by Fig. 13 has been met with several times in the last few years. It consists of a reaction turbine working between two reservoir basins with varying water levels. Two main alternatives may then be considered.

The first consists in putting the tail water gallery of the turbine under pressure to avoid any head losses between the two reservoirs. In this case surge tanks are necessary both upstream and downstream from the turbine, and the main problem for solution is that of stability of oscillation. As shown in Figs. 13 and 14, the oscillations in both surge tanks react

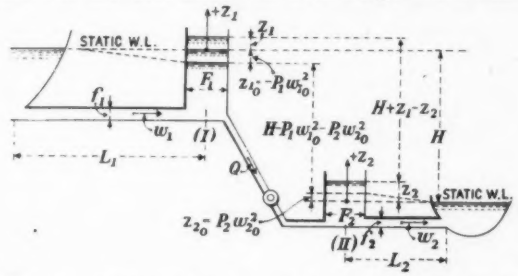


Fig. 13. *System of two surge tanks: oscillations for differently proportioned tanks shown in Fig. 14*

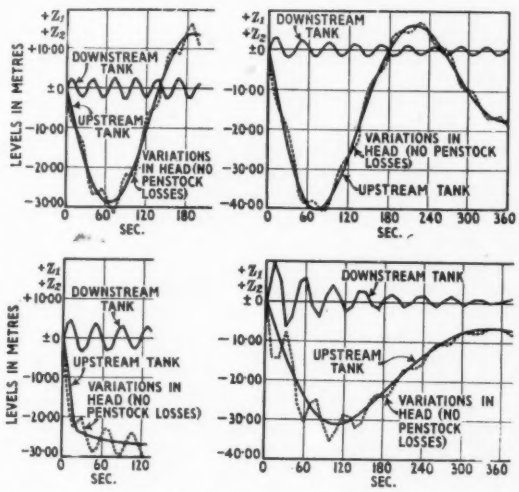


Fig. 14. *Oscillations in a system of two surge tanks, layout in Fig. 13*

LEADING DIMENSIONS

Case	I	II	III	IV.	*Units*
L_1	6330	6330	6330	6060	m
L_2	111	111	111†	270	m
f_1	7.07	7.07	7.07	7.07	m²
f_2	10.75	9.52	9.52	8.55	m²
F_1	15.95	19.64	19.64	44	m²
F_2	28.15	35.25	35.25	19.64	m²
H	261.47	273.25	235.25	261	m
Q_0	11	16.75	24	21	m³/sec
n_1/n^*_1	0.83	2.12	—	2.56	
n_2/n^*_2	1.67	1.25	1.12	2.12	

upon each other, and endanger the stability of the whole system. In this case the minimum areas chosen for the tanks should be much larger. The other alternative consists in designing a free tail race channel or gallery and allowing a certain loss of head if the

downstream reservoir level varies. Another theoretical problem is presented here by the waves in the free tail water gallery. If the tail race is short, and sufficiently inclined, and the gallery wide enough, the waves pass through without trouble. If, on the contrary, the tail race is long and sloping gently, and the gallery narrow, the waves cannot pass and another solution is necessary. This comprises a surge tank that acts only when the flow is unsteady, the tail race gallery being then under pressure whereas when the flow is steady it passes through the tail race gallery without putting it under pressure.

This solution with partially-acting surge tank was first put into effect at the Wettingen Hydro-Power Development (Fig. 15) after thorough investigation both by calculation and with a model. The Wettingen Power Station has been running satisfactorily for years. The Krangede and Wettingen Development (Fig. 16) are obviously similar from the point of view of waves due to unsteady flow conditions. Another power station on similar lines has been built in Italy.

It is likely that these solutions with two surge tanks or with a partially-acting surge tank below the turbines will become the prototypes for some of the difficult hydraulic schemes of the future. Further efficient developments in applied hydraulics can be realised only by the intimate combination of theory, calculation and testing with models, and recent developments of intake works and surge tanks are typical in this respect.

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British Hydromechanics Research Association

PROGRESS in developing closer relations between the Government and the technical interests of industry is recorded by the British Hydromechanics Research Association in its first annual report, which was published at the end of last year.

This Association came into being because, as the report remarks, industrialists and Government advisers realized that British facilities for research and development in fluid mechanics were inadequate for the maintenance of a leading position in the manufacture and efficient utilization of hydraulic machinery.

A dual organization has been set up to remedy this deficiency, comprising on the one hand a projected Government laboratory with a whole-time staff, but having an advisory board and committee on which industry and academic science are represented; and, on the other, the Hydromechanics Research Association, directly controlled by industry but operating under the ægis of the Department of Scientific and Industrial Research. The general policy is to promote original research, to collect and disseminate technical information to members, and to act as liaison between industry and university and Government research laboratories.

Close contact has been made with the two D.S.I.R. sections primarily interested in hydraulics — the Mechanical Engineering Research Association and the Hydraulics Research Organization. Both of these are new and intend to provide extensive laboratory facilities. The former plans to erect a hydraulic machinery laboratory at East Kilbride, near Glasgow, and the latter, which is primarily concerned with civil engineering hydraulics, is at present using temporary accommodation at the National Physical Laboratory. Both organizations are represented on the research committees of the Hydromechanics Research Association.

The report notes that the Government is much in favour of industrial research associations, and looks forward to a rapid development of the Association to enable it to play its part in Britain's fight for recovery. The report adds that the international prestige of the fluid mechanics departments of various foreign universities has reacted to the advantage of their corresponding industries, and that it is important that every encouragement should be given to equivalent British organizations. In the past, states the report, this encouragement has been biased towards the aerodynamic applications of fluid mechanics, but although less spectacular than jet propelled aircraft, the irrigation pump and the water turbine are also of fundamental importance to humanity.

Sir John Anderson, president of the Association, says in a foreword to this first report that not only will applied research in this field assist British industry to maintain its position in the world's markets, and in so doing help to alleviate the international shortages of food and mechanical power; but also, by fostering a closer understanding between the technical interests of Government and free enterprize, enable the national creative talent to be freely developed to the best advantage.

The Association has also started the issue of an information bulletin, which is circulated only to members. An invaluable feature of the publication is the adoption of universal decimal classification for facile reference to the information abstracts from current literature.

Canada's Big Schemes

Our special correspondent, reviewing Canadian hydro-electric prospects at the start of 1949, deals with the several large developments now in hand. These projects are of vital importance because of the present power shortage.

Le Canada, comme la plupart des autres pays, est confronté par des obstacles considérables dans la recherche des moyens propres á équilibrer la puissance totale disponible et les besoins d'une industrie qui en est privée et qui se développe. Les informations les plus récentes venant de plusieurs provinces attirent l'attention sur les travaux, dont certains très importants, qui sont soit déjà en cours, soit sérieusement envisagés; et dans cette revue des perspectives hydro-électriques au Canada, à l'orée de 1949, l'auteur donne les chiffres les plus récents; ils montrent que la capacité des installations en service ne représente pas plus de 20% de la puissance disponible.

El Canáda, igual á la mayoría de los otros paises, hace frente á ciertos obstáculos al buscar medios y arbitrios de coordinar su capacidad total de fuerza motriz con su industria progresiva. Los informes mas recientes de varias Provincias se refieren á desarrollos—algunos de gran importancia—que ya están á mano ó formalmente proyectados. En este examen en Canada de la situación de las perspectivas de fuerza hidroelectrica al principio de 1949 el autor da las cifras mas recientes y que exponen que las instalaciones ya existentes representan no más que el 20% de la fuerza turbina posible calculada en caballos de fuerza.

HOW does Canada stand in hydro-electric development prospects at the dawn of 1949? With a potential among the greatest in the world the question is both pertinent and urgent—pertinent because the entire industrial activity of the Dominion is increasing rapidly; urgent because this intensified industrial drive must ever be demanding more and cheaper power. This truth applies whether we survey the closely knit industrial areas of the east, or Alberta, British Columbia, and the Northwest Territories.

It is beyond dispute, too, that there are few countries in the world where such essentials as precipitation and general topography are more conducive to water power development — the great system covered by the St. Lawrence River and its tributaries for the provinces of Ontario and Quebec, the area traversed by the Mackenzie River, and the rivers running into Hudson Bay, the potential power of which is today used in only very meagre proportions. In fact, taking the Dominion as a whole, not more than 20 per cent. of the possible turbine horse-power is represented by the installed capacity today.

Inadequate Power Supplies

Yet, as we write, 1948 has repeated the story of the preceding year in the urgency of the need for power expansion. The decision to lift the war-time restrictions on the use of power was the prime indication of this upsurge of demand, in some cases so great that—as in Ontario, for example—the controlling authorities have had to rescind their earlier policy, and issue warnings against the dangers of power shortage, alike in industrial and domestic fields. And the main cause of the warning, expressed briefly but bluntly, is that Canadian industry has gone ahead must faster than the development of power to serve it. " Staggered " hours of labour have proved at best but a very feeble palliative, for the organised workers do not react favourably to such a step, but rather take the line of criticising the provincial governments for what they hold to be lack of vision in not utilising more fully the immense power now running to waste.

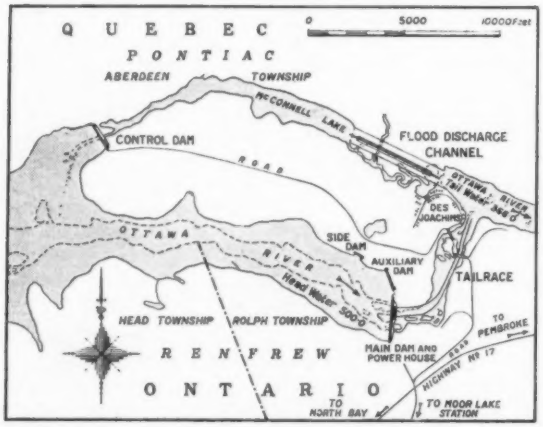
The aggregate of that power, and the extent to which it has so far been drawn upon, can be seen from the following table:—

Available and Developed Water Supplies on January 1, 1949

Provinces	Available 24-hour power at 80 per cent. efficiency.		Turbine Installation
	At Ordinary Minimum Flow	At Ordinary Six Months Flow	
	h.p.	h.p.	h.p.
Prince Edward Island	3,000	5,300	2,617
Nova Scotia	20,800	128,300	140,884
New Brunswick ...	68,600	169,100	133,347
Quebec	8,459,000	13,064,000	5,996,872
Ontario	5,407,200	7,261,400	2,894,240
Manitoba	3,309,000	5,344,500	506,825
Saskatchewan ..	542,000	1,082,000	111,835
Alberta	507,800	1,258,000	106,560
British Columbia .	7,023,000	10,998,000	1,009,769
Yukon and North West Territories ..	382,500	813,500	28,069
CANADA ...	25,722,900	40,124,100	10,931,018

Figures in the second and third columns, it should be pointed out, are based upon rapids, falls and power sites of which actual drop, or the head possible of concentration, have either been measured or carefully estimated. There are, of course, many unrecorded rapids and falls of undetermined capacity, which will be tabulated when detailed survey work has been completed. Further, unless results of prolonged studies are placed on record, no regard can be paid to power concentrations that are feasible on

Outlets from Toronto power plant reservoir on Dufferin Island, part of the Queenston plant, largest in Ontario (560,000 h.p.) and below, map showing general arrangement of Des Joachims Development



waters of gradual gradient, where economic heads might be created by the construction of power dams. Taken as possible heads, therefore, the table represents only the minimum water power possibilities of this vast Dominion. "Ordinary minimum flow" is the average of flows for the two lowest periods of seven consecutive days each year over the recording period; while "ordinary six months flow" is the computed dependable stream flow usually available for at least six months.

A further factor to be remembered when reading this table is that generally it is accepted as sound commercial practice to have capacity to utilise the six months flow. In some cases deficiency in power at lower flow is overcome by storage dams; in others by connecting with plants operating under different load conditions, or by some form of auxiliary power. Analysis of installed capacity of a number of such plants across Canada shows that average capacity of turbine installation is 30 per cent. greater than the power equivalent of the six months flow. The estimates of maximum available power are thus made on a conservative basis. This being so, the total recorded water power resources of the Dominion will allow a turbine installation of well over 52 million h.p.

Des Joachims

Canada, like most other countries, faces considerable handicaps in seeking ways and means of bringing her over-all power capacity more nearly into relation with her advancing and power-starved industries. But as Mr. Churchill, the British Prime Minister in the war, said of a task of even greater importance and urgency: "I do not want to hear too much about the difficulties—they will argue for themselves"; and

No. 2 Powerhouse and headblock at Shipshaw, Quebec Province. These and the canal were completed in record time of 30 months

Canada is making bold strides. The latest information from several provinces refers to development schemes, some of them of considerable magnitude, which are either in hand or seriously contemplated. Ontario is one province making really appreciable headway. Following the opening, nearly two years ago, of the 70,000 h.p. unit in the DeCew Falls plant, construction was begun on four major projects which, among other advantages, would help in relieving the now acute shortage of prime power during peak load periods in the heavily industrialised southern part of the province.

Of these four schemes by far the most important —indeed it has been described as the biggest undertaking by the Hydro Electric Power Commission of Ontario since Niagara—is that at Des Joachims rapids, on the Ottawa River nearly forty miles above Pembroke, with an ultimate capacity of 358,000 kW (480,000 h.p.). Construction began in 1946, and the first four of the eight generating units are scheduled to go into operation next year; the remainder in 1951. The operating head will be 130 feet, and power will be carried by 230 kV overhead transmission lines some 200 miles to the service area.

Clearing work has involved 11,000 acres between the site of the works and the village of Mattawa, 57 miles distant, and 22 miles of railway and twelve miles of highways have been diverted and rebuilt. Eight 22 ft. diameter steel penstocks will convey the water to the turbines in the power house at the base of a gravity type dam, approximately 2,400 feet in length and with a maximum height of 190 feet. A tailrace channel, about 7,000 feet long and 150 feet wide is being excavated through rock in the rapids stretch of the river, and to the north of the main dam will be an auxiliary one approximately 1,300 feet long with a maximum height of 65 feet. The McConnell Lake valley, north of the Ottawa River, is to be utilised as a flood discharge channel, with a control dam at the western end to prevent overspill into the valley from the raised water level above the main dam. This control dam will be about 1,600 feet long, with maximum height 130 feet, and will include forty 16 foot stop-log sluices and six 40 foot sluiceways with steel gates. The Atlas Construction Company has been entrusted with this work, under the supervision of engineers of the Hydro-electric Commission.

"Bailey Bridge" Structures

At the time of writing construction activity is going forward on both the Ontario and Quebec sides of the Ottawa River. Advantage is being taken here of practice which had its inception in Europe under the stress of war, including the erection of Bailey bridge structures to support the components of aggregate

screening plant. There are now roughly 2,000 workers engaged on these sites, but as the work reaches its peak the total force will be increased by at least another thousand. The estimated cost is 57½ million Canadian dollars, and about 25,000 people will depend upon the project for daily subsistence.

So much, then, for one of Canada's biggest schemes of power expansion now under construction. There are others, both in Ontario and Quebec, that are calculated greatly to increase power supply. One major project for Quebec is that of the Shawinigan Water and Power Company at Shawinigan Falls, on the St. Maurice River, where the new power house is designed to develop 195,000 h.p. in three units. Manitoba, foremost of all the prairie provinces both in power resources and in their development, has in the past year made progress on the Dauphin and Churchill rivers following preliminary investigations and surveys by the power commission of the province. Alberta, with its capital Edmonton, natural head of hemispheric travel and defence, and its wealth of valuable minerals, is today contemplating development of hydro-electric power to serve industry and the population right up to the border. A commission from Britain included Mr. J. Maxwell Buist, director of the British Electrical and Welding Manufacturers Association (London), and Mr. J. W. Golsby, of the Board of Trade Export Promotion Department. At the beginning of October there were close on 90 hydro-electric plants in the province, with an annual production of electrical energy standing at 650 million kWh. The potential water power of Alberta, however, is 1,050,000 h.p. at ordinary six months flow and 390,000 h.p. at ordinary minimum flow. Of this less than 125,000 h.p. is at present developed; but two schemes, respectively to serve the north and south, are the subject of advanced preliminary work.

Fundy Bay Project

While these are among the schemes within the scope of reasonable achievement, in the more distant future, yet already advocated by experts and other leaders of industry both in Canada and the United States, is the gigantic conception of harnessing the tides of Fundy Bay—that turbulent arm of the Atlantic lying between the eastern extreme of Canada and the American State of Maine. Daily rise and fall of water here averages 40 feet, and an almost astronomical tonnage of water surges in and out of the bay—a mammoth power potential and, in these days of shortage, a colossal waste of energy. For many years the conversion of this tremendous natural force to power has been a matter of keen discussion and expert investigation. Between the two world wars the late President Roosevelt showed a marked interest in the plans of the United States electrical engineer, Dexter Cooper, but the 10 million dollar scheme—known as the "Passamaquoddy" project, from the shore area at the mouth of the bay—was dropped during the attacks on "New Deal" planning by the President. Before that happened, however, there had been much preliminary work at the site, and the small town of Passamaquoddy had been created, only, alas, to become virtually deserted when World War II. put the scheme right out of consideration.

Public interest is being revived in the project today, but whereas Mr. Roosevelt envisaged the expenditure of something like 10 million dollars on the scheme, the sum now mentioned is ten times that figure. It is supported, among others, by the woman senator for the State of Maine—Mrs. Margaret Smith—who is urging the Government of the United States to take up the project from the point at which it was left 13 years or so ago.

Broadly speaking, the plans provide for two great basins to ensure a constant flow of water through the turbines, coinciding with the rise and fall of the tides. The scheme, in the considered opinion of United States engineers, would be capable of producing up to a million h.p., and it has been their hope that the Canadian Government would participate financially in the undertaking; but so far it has not committed itself, the chief obstacle at the moment being that of cost. Canadian engineers are largely in agreement on the desirability of putting the scheme into operation, but raise an oft-heard argument—that the cost of producing electricity from the tidal waters would be greater than the process of production by coal.

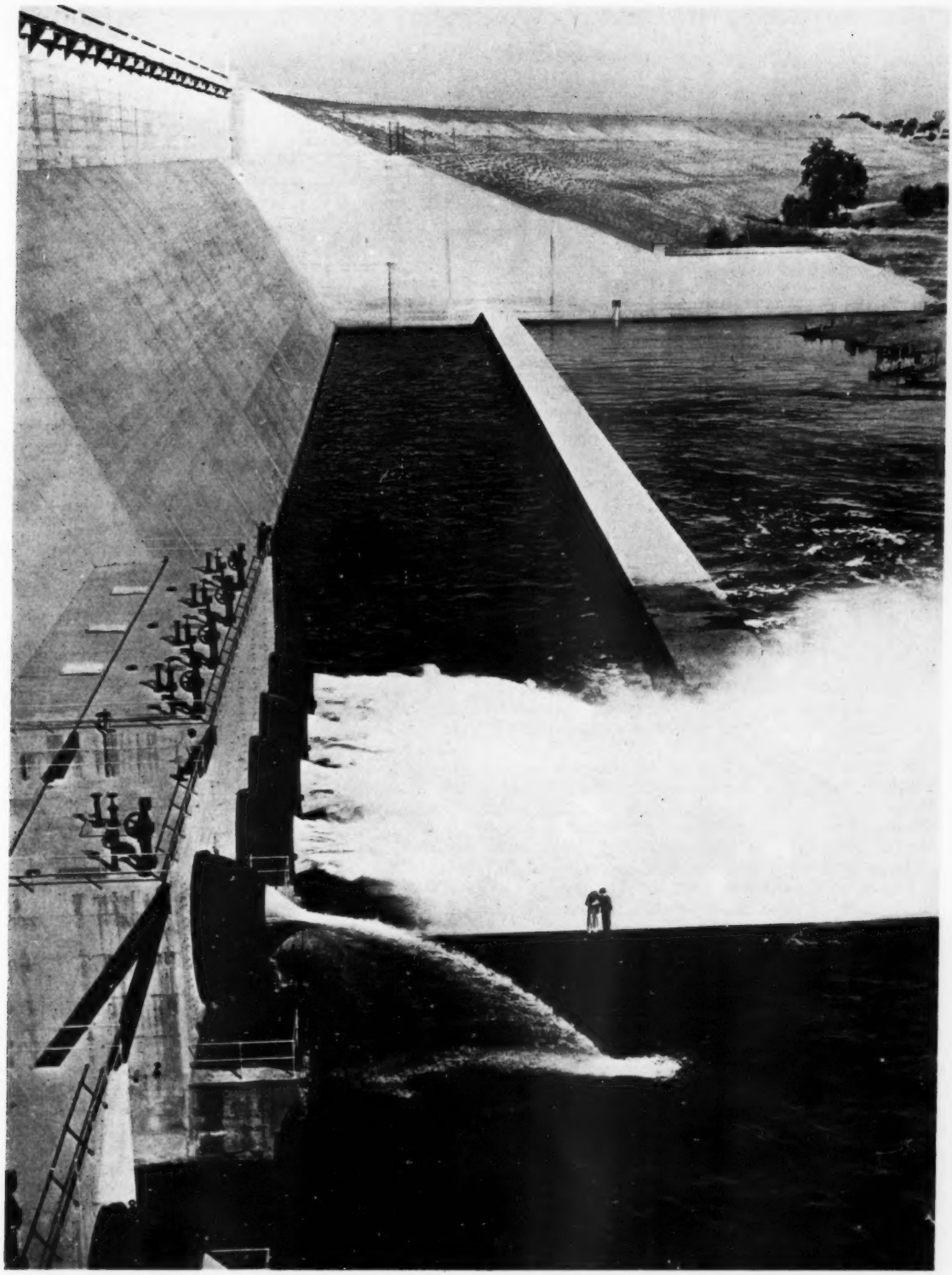
But the full story of coal has not materialised. As a mineral of the greatest value, its maximum worth to the world awaits far greater exploitation than so far has been achieved. When research has accomplished that work water power unquestionably will become a main source of electrical energy, with Canada in the vanguard.

World Power Conference

The British national committee of the fourth World Power Conference, which will be held in London in July, 1950, has issued a technical programme dividing the conference's main theme of "World Energy Resources and the Production of Power" into three sections. The first will include a survey of the energy resources of each member-country, and a historical record of the development of those resources since 1924; the second is to be devoted to individual papers dealing with the preparation of fuel of all kinds; and the third, which is perhaps the most important, is headed "Production of Power." In this, apart from the traditional sources of power, papers will be included on gas turbines, jet engines, hot air engines, tidal power, wind power, solar energy, terrestrial heat, thermal energy derived from the sea, and atomic energy.

In the section of the technical programme dealing with the production of power, the committee comments that the world tendency towards higher fuel costs and lower rates of interest on capital has given a new stimulus to hydro-electric power developments. Construction methods have been improved and projects for new plants and the modification of existing plants to achieve greater efficiency are in train, many of which present features of special interest. The committee adds that wind power has likewise attracted more attention because of the prevailing power shortage, and that the time seems opportune to re-examine the potentialities of this source, which was at one time so valuable but has fallen into disuse.

The national committee points out that since the first World Power Conference met in London in 1924, there has been a period of phenomenally rapid technical progress. It is hoped, therefore, that the contributions as a whole will provide a world survey of the present and future developments of the subjects falling within the theme of the conference.



The great Hume Dam, in Victoria, stores 1,250,000 acre-feet of water. Its wall is just over a mile long and it holds back the largest sheet of fresh water in Australia

The Karapiro Station

Three of the largest water turbines yet built in Great Britain have recently been installed in New Zealand, where they use the waters of the Waikato River to generate electricity.

Trois des plus grandes turbines hydrauliques jamais construites en Grande Bretagne ont été récemment installées à la station de Karapiro en Nouvelle Zélande; elles y transformeront en électricité la puissance des eaux du fleuve Waikato. Au cours des essais conduits sur place ces turbines ont largement dépassé le rendement garanti et elles donnent maintenant complète satisfaction. Certains détails de construction sont donnés. D'autres projets sur le Waikato sont évoqués, dont le but ultime est un débit de 835 000 kW grâce à la chute des eaux entre le lac Taupo et l'eau d'aval du barrage de Karapiro.

Tres de las mas grandes turbinas hidráulicas construidas hasta hoy en Inglaterra han sido recien instaladas en la estación de Karapiro en Nueva Zelandia (donde se utilizarán las aguas del Rio Waikato para generar la electricidad). Ensayos hechos en el mismo sitio han demostrado que las máquinas han superado en mucho la eficiencia garantizada y dan la mas completa satisfacción. Se dan algunos detalles referente á la construcción del aparato, y se hace mención tambien de varios otros proyectos en el mismo sitio del Rio Waikato que al fin y al cabo darán un rendimiento de 835,000 kW de la bajada disponible del rio entre el Lago Taupo y las aguas de la Represa de Karapiro.

THE State Hydro-Electric Department of New Zealand has planned a series of hydro-electric power stations on the Waikato River which will ultimately have a total installed capacity of 835,000 kW. The Waikato is the largest river in the North Island and issues from Lake Taupo, which provides a large storage capacity and ensures a relatively steady flow of water throughout the year. The first part of the scheme has recently been completed.

It included an extension to the Arapuni station, which is the first to use the waters of the Waikato River after it flows from the lake; and the construction of an entirely new hydro-electric power station downstream at Karapiro, where three of the largest water turbines yet built in Great Britain have been installed.

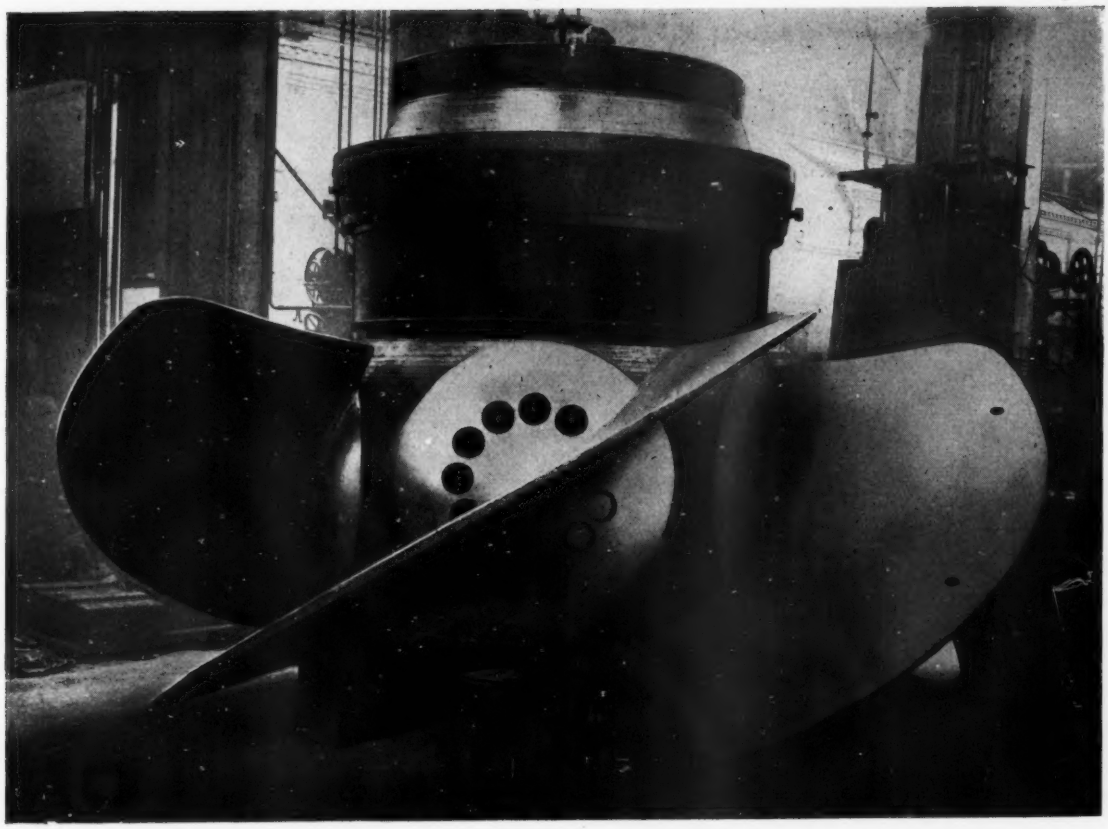
Before the construction of the Karapiro station there were still two hydro-electric stations on the Waikato. The first was the Horahora station which was started up in 1911 and finally consisted of eight units with a total capacity of 10,300 kW. This station served its purpose well and gave excellent reward throughout a long life; but it is now submerged in the new lake formed behind the dam to serve the Karapiro turbines. The second station is at Arapuni where a most economical development has been possible. The station, which was completed to full capacity in 1946, comprises four 15,000 kW A.S.E.A. units driven by Armstrong-Whitworth turbines and four 21,250 kW Metropolitan-Vickers units each driven by 30,000 b.h.p. Boving Francis turbines.

The first unit of the Karapiro Station was commissioned in April 1947; the second in September 1947 and the third in May 1948. The scheme comprises an arch dam across the river with the power station on the right bank immediately at the foot of the dam. The normal effective head will be approximately 100 ft., and the range of variation in the dam level will be relatively small.

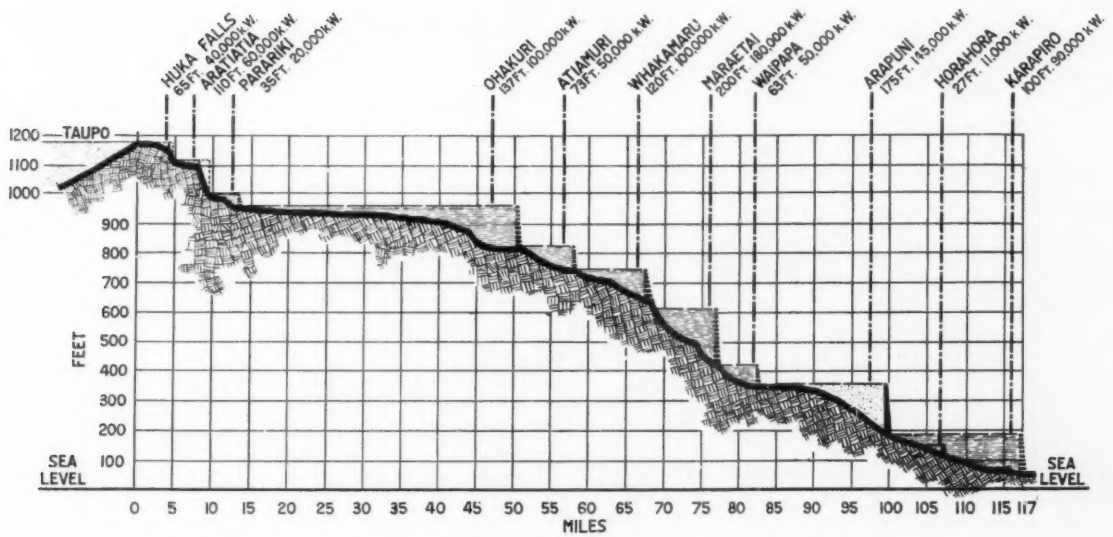
The Karapiro units are the largest Kaplan turbines yet installed in New Zealand or Australia, and there are three of them each of 42,000 b.h.p. output, built by Boving and Company, of London. Each turbine is served by a steel penstock of 21 ft. in diameter which has been designed and constructed entirely in New Zealand. In addition, all the plate work in the suction linings and spiral casings was fabricated and erected locally, this being the first occasion on which such relatively complicated steel plate construction has been undertaken in New Zealand. The design of the draft tubes was a vital factor affecting the excavation and lower foundations for the power station. For practical reasons a vertical division wall was required in the horizontal draft tube outlet, but efficiency could not be sacrificed to this requirement. Model tests were accordingly carried out to determine the location and exact form of this division wall and of the draft tube outlet to ensure the highest efficiency of the turbine. The final arrangement of the plant can be seen in the sectional view.

The turbines for Karapiro were also the first large units of the Kaplan type to be designed and entirely built in Great Britain and many practical problems had to be surmounted in the course of manufacture, which commenced during the war years. The stainless steel runner blades, each set weighing eleven tons, presented some difficulties for the steel works, but close collaboration between designers and works produced a satisfactory solution. The profiles of the runner blades are, of course, of vital importance as upon their correctness depends the efficiency of the installed unit; and great care was necessary in attaining these profiles, and in finishing the surface of the blades. The diameter of the runner with blades assembled is 4,337 mm. (14 ft. $2\frac{3}{8}$ in.), and the weight of the complete assembly, excluding shaft, is $51\frac{1}{2}$ tons.

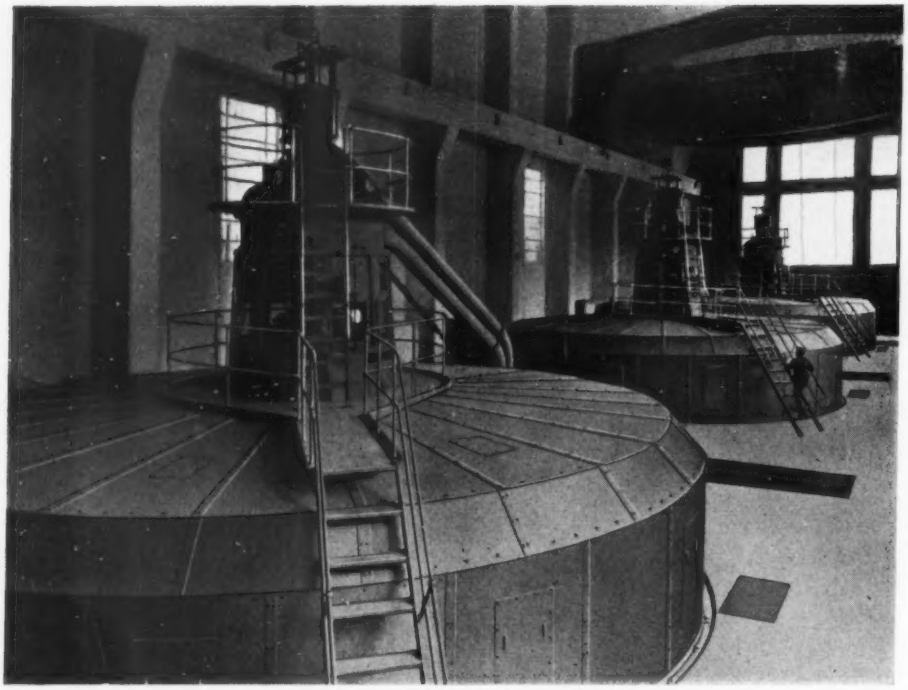
The stay ring, which leads the water into the guide vanes, carries the total vertical load of generator, turbine runner and the hydraulic thrust load. It is



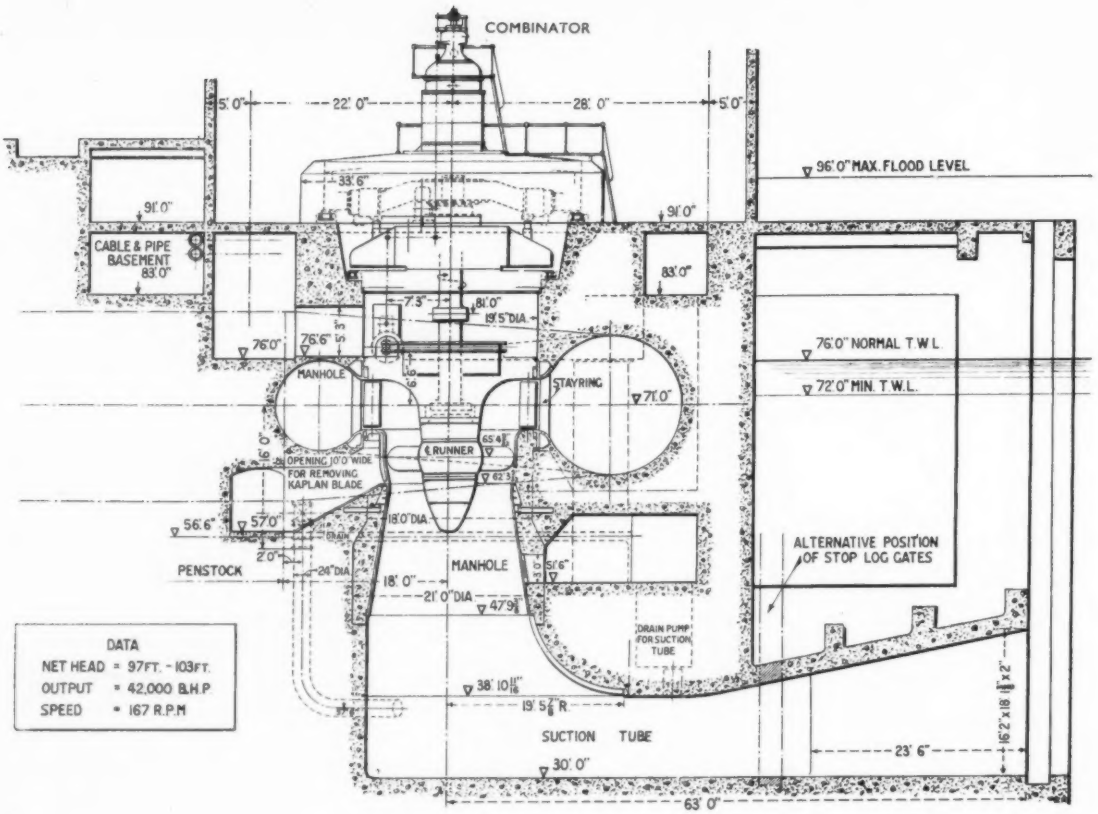
Kaplan Runner—the largest yet built in Great Britain

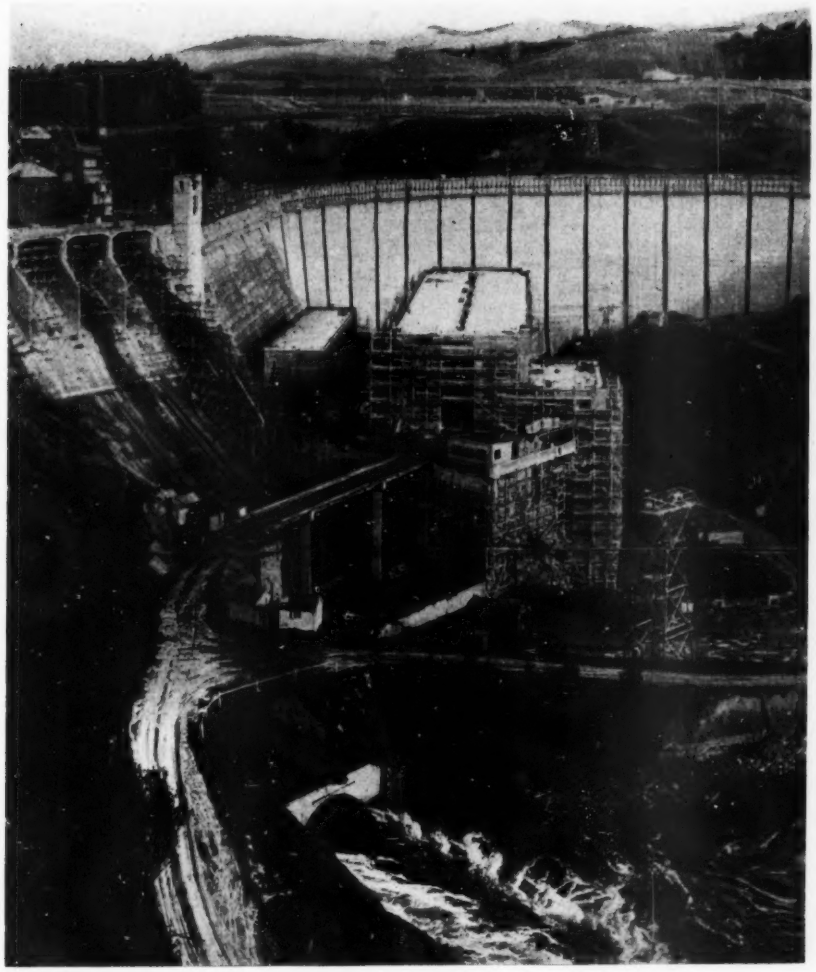


Longitudinal section of the Waikato River, showing potential hydro-electric resources



Left: The Karapiro units, each of which develops 42,000 horsepower. They are the largest Kaplan turbines yet installed in New Zealand or Australia
Below: Sectional View of Kaplan Turbine Installation





The Karapiro Power Station at the foot of the dam, with diversion tunnel outlet in the foreground

fabricated in steel plate. The stay vanes are designed not only to carry this load but with special streamline form to ensure correct flow and minimum frictional loss. The stay ring has an outside diameter of approximately 23 ft. and a total weight of 40 tons.

The spiral casing, fabricated on site, is welded to the lip plates of the stay ring; but the individual plates of the casing are welded together at the site. After assembly and before concreting the spiral casing is tested hydraulically to a pressure of 60 lbs. per sq. in. The runner chamber and the throat ring immediately below the runner are made of stainless steel, as these are the sections where cavitation effects are most likely to occur; and the chamber is designed with a removable section to permit of dismantling and removal of a runner blade. The removable section can be carried into a position below the spiral casing and the runner blade withdrawn through the opening to a point where it can be handled by the station crane, through hatches in the floors up to the generator floor level. Special suspension tackle is provided for removal of a runner blade and this tackle when applied to all five blades is also used to support the complete runner. This suspension arrangement, which is located above the runner centreline, obviates the necessity of providing any heavy supporting members or staging for dismantling operations.

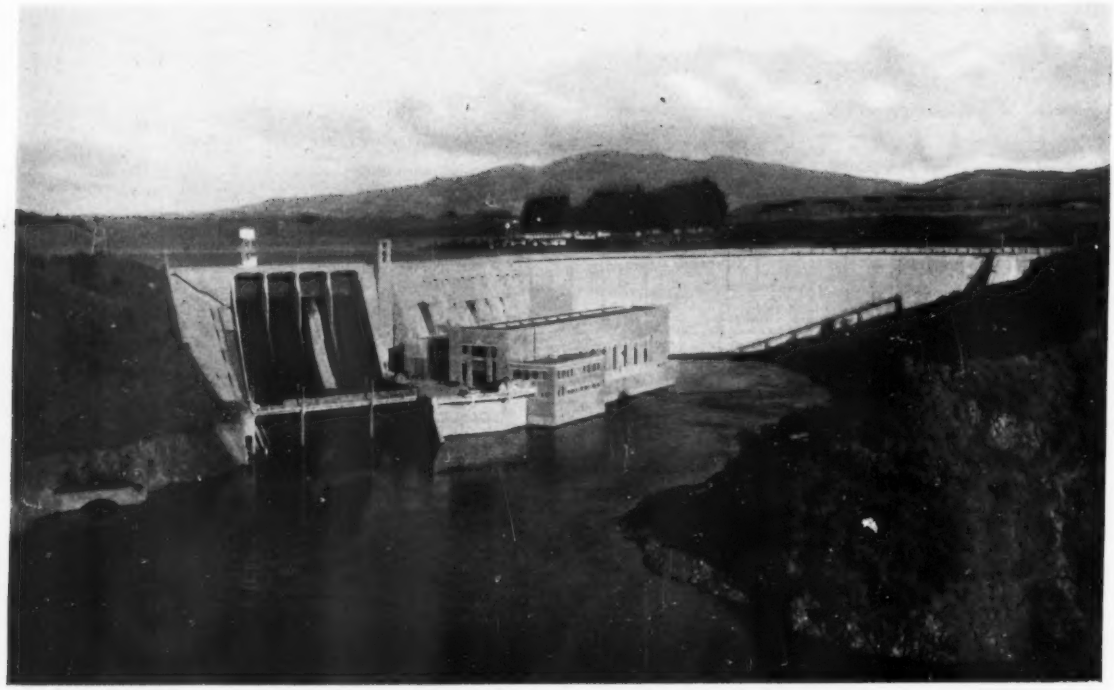
The guide apparatus is of conventional design, but to secure minimum leakage when the guide vanes are closed special rubber sealing strips are provided at the line of contact between adjacent vanes.

The speed sensitive element of the governing system comprises an actuator of latest design with pendulum motor supplied by a separate auxiliary generator of the permanent magnet type mounted in the main alternator shaft. This auxiliary generator is coupled electrically to the pendulum motor and no other supply is taken off the circuit. The actuator controls and operates a regulating valve, which in turn operates the main servomotor. This main servomotor is coupled by a short connecting rod direct to the regulating ring running on a train of rollers to ensure minimum frictional load, and to remove any possibility of side thrust. The regulating ring is connected to the guide vane levers by means of breaking links, which under a predetermined overload will fail, thus protecting the remainder of the guide apparatus.

In addition the actuator controls the combinator mounted on top of the alternator. This combinator is connected through the hollow shafts to the regulating valve in the runner hub, and so controls the admission of pressure oil to the servomotor cylinder within the hub. Pressure oil to the governing system is supplied by a conventional pumping unit provided with a high efficiency Imo pump driven by a direct coupled motor.

Efficiency tests have recently been carried out on one of the Karapiro units at site and these tests show that the guaranteed efficiencies have been exceeded by some 2 per cent. Reports from site indicate that the units, which have been running almost continuously since putting into service, are giving every satisfaction.

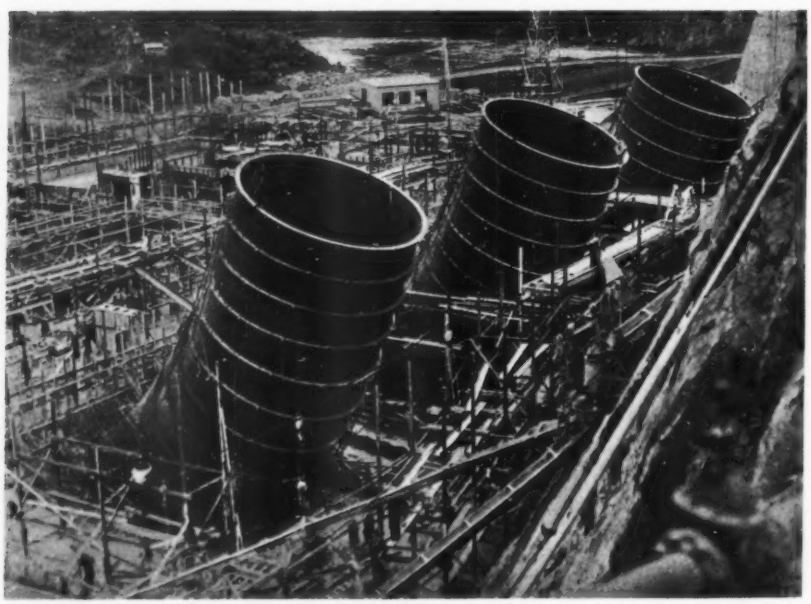
Of the remaining projected developments on the Waikato River the next station to be built is Maraetai. The turbines and generators have already been



ordered from America and preparatory work at site has commenced. This station will comprise five vertical shaft Francis turbines with steel plate spiral casings each designed for an output of 50,000 b.h.p. at 167 r.p.m. under a net head of 195 ft. Each turbine will be served by a penstock 16 feet in diameter, and the shut-off valve will be located adjacent to the inlet to the spiral casing. The turbines will be direct coupled to 40,000 kVa generators, and this plant when completed will comprise the largest power station in New Zealand.

An arch dam will span the river gorge and the power station will be constructed immediately at the foot of the dam to give the shortest practicable length of penstocks. The spacing between units also has to be kept to a minimum as the available space for the length of the building is limited. The designs for the dam have been completed and they provide for diversion of the river (during construction) past the dam in a tunnel, the general arrangement being similar to that adopted during construction of the Karapiro dam.

The site of the Maraetai installation is roughly midway between the Waipapa and Whakamaru projects. It is intended therefore to erect a semi-permanent village near to Maraetai, and use this as the construction camp for all three projects, and doubtless as a central headquarters village when all three stations are in commission.



Investigations are now in hand at the site of the Whakamaru project, such as test bores, exploratory shafts, etc.; these preliminary investigations are essential for deciding on the final location of the dam, which must be known before the exact hydraulic conditions for the turbines can be settled.

Top: The Karapiro dam
Left: Penstocks during construction

From the Journals of the technical institutions, and other material published in the Press of the World

Large vertical-shaft Turbo-alternators

In their paper discussing the design of large vertical-shaft water-turbine-driven a.c. generators, Messrs. E. M. Johnson, M.Sc.(Tech.), M.I.E.E., and C. P. Holder, B.A., A.M.I.E.E., refer to generators of large diameter in the speed range 50—500 r.p.m. The basic problems are considered and various alternative solutions are indicated.

The two principal factors in the determination of the choice of speed for a water turbine are the available load and the output required. For a given output the speed falls with the head, and for a given head the speed falls with increasing output. Turbines of large output and low head, therefore operate at very low speeds. In consequence, generators driven by such turbines are of large dimensions involving many problems in design and manufacture due entirely to their physical size. The governing of water-turbines presents a serious problem because of the great inertia of the moving mass of water and as a result generators driven by water-turbines have often to be built with very high flywheel effects.

The turbine and hydraulic characteristics summarized in terms of their consequential effects on the mechanical design of the vertical shaft generator are thus:—

(a) The generator will almost invariably be of the salient-pole type, and may be of low speed and very large diameter.

(b) The rotating parts will usually be required to embody a flywheel effect greater than would otherwise be normal in order to ensure satisfactory governing.

(c) The rotor must be capable of withstanding the stresses produced by running at the maximum over-speed of the turbine.

(d) The lowest critical speed of the rotating system should be above the maximum turbine over-speed.

(e) A thrust bearing must be provided to take the weight of the generator rotor and turbine runner and the hydraulic thrust.

Factors which determine the generator dimensions are enumerated and discussed and it is stated that the electrical characteristics effect the dimensions to a limited extent only. The problem facing the designer is that of proportioning the cylindrical volume by choosing the diameter and axial length most suited to the particular case.

A simple and convenient generalization is made relating the flywheel effect and the diameter of machines of the type under review; curves are plotted on this basis and an example illustrates their use in determining the approximate diameter for any given operating conditions. A detailed review of different types of rotor and pole construction and their range of application is offered.

An important feature of this type of machine is the thrust bearing and its support which carry very heavy loads. The general considerations covering alternative types of bearings, and the arrangement of the thrust and guide bearings, are enumerated; details of design are given; and the merits of the various arrangements compared. Methods of cooling bearings are also described. Details of the special arrangement of air coolers required for this class of generator are given and reference is made to the use of generator ventilating air for station heating.

Then follows a description of the arrangement and the method of operation of brakes and jacks. The stator frame, core and windings; the rotor windings; the exciters and governor generator are briefly described and considered; and the paper concludes with a brief review of the special electrical characteristics of this type of a.c. generator.—*Paper read before the Institution of Electrical Engineers, Newcastle-upon-Tyne, on November 8th, 1948.*

High Voltage D.C. transmission

Lord Forrester, M.A., M.I.E.E., and Mr. F. J. Erroll, M.A., A.M.I.E.E., M.P., in a joint paper before members of the Institution of Electrical Engineers, state that the present energy famine makes necessary the development of new power resources, some of which are remotely situated. They suggest that in these circumstances, transmission of energy by high voltage direct-current can be of service, and they urge interested parties to consider whether experimental installations should be set up, which would permit the manufacture of suitable equipment to proceed on a commercial scale.

Alternative sources of power include water power, geothermal energy, tidal power, wind power, solar energy, atomic energy and, in the field of prime movers, the gas turbine. Water power is numbered among the most important of these sources. It is stated the power in a river is directly proportional to the product of flow and head. Before 1933, the high head station gave the best results, and examples of the fast running reaction turbine can be seen all over Europe. The past fifteen years have seen a great increase in the use of large slow speed units and their development has made possible the harnessing of rivers with medium and low head falls. Sweden and Finland are examples of countries mainly dependent on hydraulic energy whose waterfalls in or near the consuming areas have been developed to capacity. Both are now developing resources within the Arctic Circle, and 500 miles from consuming areas.

Alternative sources of power are described and their connection with the development of high voltage d.c. transmission is emphasised. Estimated costs of transmitting 2,000 MW over 370 miles in

four ways are quoted in support of the continental opinion that d.c. transmission is both possible and economically desirable. Descriptions of types of cable suitable for land and sea routes; overhead lines; and equipment for rectification and inversion are mentioned and some technical aspects of the problem are reviewed.

Four projects favourable to d.c. transmission of hydro-electric power are then briefly outlined. They are from Norway to Denmark, from Tasmania to the Australian mainland, in Central East Africa, and from Tibet to India.

The authors conclude with a reminder that the 500 yard section of 132 kV gas compression cable connected in series with overhead grid lines in Yorkshire in 1944 has given four years of satisfactory service. They suggest that by similar and more extensive cooperation a large scale experiment with d.c. transmission by cable and overhead line might be undertaken in the British Isles.

Water turbine machinery analysed

At a meeting in Glasgow on December 14, a paper on "Water Turbine Machinery" was read before members of the Institution of Engineers and Shipbuilders in Scotland by Mr. A. A. Fulton, B.Sc. The author stated that although the development of water turbines had involved much exacting work, few people, other than the manufacturers and designers, understood the considerations which decide the type of turbine to be used in a particular case.

For a given set of conditions the problem of balancing the cost against the maximum output involves a consideration of speed, reliability and the type of load to be met. Francis, Kaplan and Pelton turbines are described, and the relationship between efficiency and output discussed.

Specific speed is defined as the speed at which a water turbine runner will rotate under unit head when developing unit power. The three types are ranked in order of ascending speed thus:—

Pelton Turbines	—	Under 10 British Units
Francis Turbines	—	15—100 „ „
Propellor or Kaplan Turbines		100—230 „ „

The simplicity of Pelton turbines and their comparative freedom from cavitation troubles are noted and there are some remarks on the design and fixing of the buckets. The limitations of the fixed blade propellor type turbine are illustrated by a comparison of performance with those of Francis and Kaplan turbines.

Conditions giving rise to cavitation are explained and the adverse effects of this phenomenon on Francis and Kaplan turbines are described. It is stated that if a suitable relationship between barometric pressure, suction head and total head is maintained, cavitation can be avoided; this relationship being known as the cavitation factor.

Due to the complexity of the pressure conditions for any given runner, it is difficult to evaluate this factor by analysis. It is more readily determined experimentally by model testing. The type of turbine most suitable for a given head is stated. Thus the application of Kaplan turbines is limited to heads below 150 feet. Francis turbines share the field above 150 feet with Peltons, but above 1,000 feet there is no alternative to a Pelton turbine.

It is stated that due to the incompressibility of water, speed regulation of water turbines presents greater problems than occur in the control of any other prime mover. These problems are discussed and illustrated, and the importance of correct pipe line design and the provision of adequate means for dealing with surges is stressed.

Contractors' Notes

Allis-Chalmers Manufacturing Company. — As expansion of hydro-electric capacity throughout the U.S.A. continued in 1948, increased production was matched by a mounting flow of orders for hydraulic turbines and equipment. Important orders of the year include three 52,000 h.p. (best load), 190 ft. head, welded casing units for the Bull Shoals Development; four 105,000 h.p. 400 ft. head, welded casing turbines to be installed at the Hungry Horse Development; and an 82,500 h.p. 280 ft. head unit for the New Gorge power house extension of the City of Seattle.

Four large cabinet type governors and accessories were ordered for the 111,300 h.p. turbines to be installed later at the McNary Dam in Oregon. Also completed and shipped was the fifth Allis-Chalmers 103,000 h.p. turbine and governor for the Shasta Dam.

An outstanding order received during the year was for two 82,500 kVA generators for Hoover Dam. Because of their inherent operating characteristic requirements, these generators will rank among the largest of their type built by Allis-Chalmers, both in rating and in physical proportions. Other noteworthy orders received included two 16,667 kVA units for Whitney Dam, three 42,100 kVA units for Bull Shoals, and four 12,500 kVA generators for Fort Gibson. For governor drive on a hydraulic turbine generator now under construction, a special exciter is provided with a three-phase take-off for powering the small governor motor, whose speed is thus synchronized with that of the generator. By careful pole design, phase shift is minimized, giving a simpler, more accurate, governing mechanism.

Boving and Company.— During 1948 a further order was received from the North of Scotland Hydro-Electric Board for a 42,000 b.h.p. Pelton turbine for the Lawers Station. This machine will be the largest Pelton turbine yet installed in Great Britain. The erection of the first Clunie turbines was started during the year. This station will comprise three vertical shaft Francis turbines each designed for an output of 28,700 b.h.p. with a net head of 253 ft. Manufacture of the two Kaplan turbines for the Pitlochry Station is well advanced. These units are vertical Kaplan turbines to be placed in spirals formed in concrete. Each unit will develop 10,900 b.h.p. under a head of 47 ft. The third station of the Tummel-Garry scheme is Errochty and manufacture of the three 35,000 b.h.p. Francis turbines is proceeding steadily.

New Zealand.—The third of the 42,000 h.p. Kaplan turbines was commissioned early in 1948 at the Karapiro Station and all three turbines are now in commercial service. Efficiency tests were carried out in the latter part of the year and the results gave a handsome margin over the guaranteed figures. The two 21,000 h.p. Francis turbines for the Kaitawa Station were also commissioned and these are of interest as the station is to be automatically controlled from one of the other stations in the Waikaremoana group. Erection of the fifth unit at Waitaki was commenced during the year and this 23,000 h.p. Francis turbine should be in service early in 1949. An order for two 14,000 b.h.p. Pelton turbines for Cobb River was received from the State Hydro-Electric Department. These units are single runner twin jet horizontal machines operating under a net head of 1,830 ft.

Tasmania.—In the face of severe competition an order for three 35,000 b.h.p. vertical Francis turbines was secured for the Tungatinah Station. These units are of particular interest as they are to operate under a net head of 950 ft., unusually high for Francis turbines, and special materials will be used in their construction. Each machine is also provided with a 48 in. diameter Boving patent rotary valve which is being manufactured entirely in Australia.

Spain.—A number of important orders have been secured; the most notable being three 74,000 b.h.p. vertical Francis turbines for the Los Peares plant and two 59,000 b.h.p. Francis turbines for the Salto de Castro installation. The Los Peares units rank among the biggest machines in terms of output yet built in Great Britain while the Salto de Castro turbines are of interest because of the large runner diameter, which is 14½ feet.

India.—The first four 19,000 h.p. Pelton turbines have been installed and started up in the Jog Falls Station for the Government of Mysore, and were in commercial service by the end of 1948. Delivery of the turbines for the extension of this station has commenced. These units are double runner 4 jet horizontal shaft Pelton turbines each designed for 32,500 h.p. under a net head of 1,190 ft. The shaft, bearings and runners of each unit are manufactured and assembled in Britain and after inspection shipped to site. The generator rotor manufactured by the I.G.E. Co., New York, is shrunk on to the shaft at site and this is an interesting departure from the normal procedure of generator construction. The installation of the three 4,250 b.h.p. Kaplan turbines for the Muhammadpur Station on the Ganges canal has progressed steadily during the year, and the first two units should be in commercial service early in 1949.

Uganda.—An interesting order has been placed in Great Britain for the Owen Falls scheme sited on the White Nile just below its outlet from Lake Victoria. The order covers three Kaplan turbines each designed to develop 21,000 b.h.p. under a net head of 62 ft., while running at a normal speed of 150 r.p.m. This will be the first large Kaplan turbine installation in any of the African Colonies and the whole scheme is in effect a most interesting example of large scale development of hydro-electric power resources in Africa.

The British Thomson-Houston Company. — The largest of many orders for hydro-electric plant received during 1948 covers the complete equipment—comprising turbines, alternators, transformers, switchgear and auxiliaries—for the Los Pearas Power Station of Fuerzas Electricas del Noroeste S.S., Spain. This power station will house three B.T.H. vertical alternators, each of 62,400 kVA, driven by turbines supplied by Boving & Co. Ltd., as sub-contractors. A further order from Spain comprises three vertical alternators, each rated 6,500 kVA, all the associated transformers and switchgear.

For the Owen Falls Hydro-Electric Scheme, Uganda, four vertical alternators, each rated 16,700 kVA have been ordered, and for Norway the company has in hand an 18,000 kVA vertical waterwheel alternator for Bardfoss Power Station, a 14,000 kVA horizontal alternator for Olderend Power Station, and a 4,000 kVA alternator for Selbu Power Station.

During the year three 4,375 kVA sets for Muhammadpur Power Station, India, were shipped. An order for a horizontal 29,500 kVA alternator for Lawers Power Station has been received from the North of Scotland Hydro-Electric Board, and the first of three vertical waterwheel alternators for the board's Clunie Power Station has been despatched.

Gilbert Gilkes and Gordon. — A 4,250 b.h.p. twin-runner unit of the Turgo Impulse type destined for the Marmoles y Cementos del Nare, Colombia, South America, is nearing completion. This unit is of particular interest in that it is to replace two Francis type turbines of foreign manufacture which have proved unsatisfactory due to heavy wear caused by the large amount of silt and sand carried in the water of the River Nare. The General Electric Supply of Curepipe, Mauritius, which has two 3,000 b.h.p. Gilkes Turgo Impulse Turbines at work, has during 1948 placed a further order for a 4,500 b.h.p. turbine of the same type which will augment the output of the power station.

Electricity for the romantic Isle of Skye will be provided by two 1,200 b.h.p. Gilkes Francis Turbines ordered for the Storr Lochs scheme of the North of Scotland Hydro-Electric Board. A new form of governing system designed to obviate the necessity for the conventional governor operated relief valve was demonstrated to consulting engineers at Gilbert Gilkes and Gordon's works in 1948. Two orders have been received, one of which is for the Gairloch station of the North of Scotland Hydro-Electric Board, incorporating this new system.

The English Electric Company.—In a comprehensive report on the year's activities, it is stated that an order for two further hydro-electric units for Sengulam power station in Travancore State has been placed with the company, making a total of four 18,000 h.p. generating sets. Each set consists of a horizontal impulse water turbine of the double-runner type, with each runner actuated by two jets under a head of 1,130 feet, driving a 12,000 kW, 11 kV, 3-phase 50 cycle alternator at 500 r.p.m. The contract includes cylindrical balanced valves, power station switchgear and transformers.

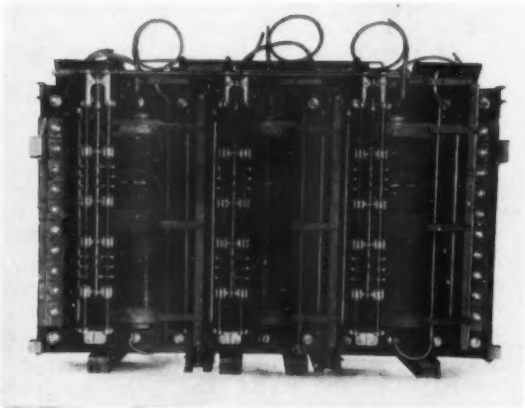
The Newfoundland Light and Power Company ordered a third generating set for the Tors Cove installation, comprising a 3,550 h.p. horizontal overhung reaction turbine driving a 2,500 kW alternator.

Rapid progress is being made with the site work for the hydro-electric plant at Castelo do Bode in Portugal, where the three draft tubes for the 73,000

h.p. " English Electric " turbines are now in position.

Site work is also proceeding for the Loch Sloy installation of the North of Scotland Hydro-Electric Board, and the four draft tubes for the company's 45,000 h.p. vertical reaction turbines are now erected.

Hackbridge and Hewittic Electric Co. — Of special interest are two 60 MVA three-phase type OFW transformers for hydro-electric plant now in course



Core and coils of a 45,000 kVa Hackbridge transformer showing the five limb construction

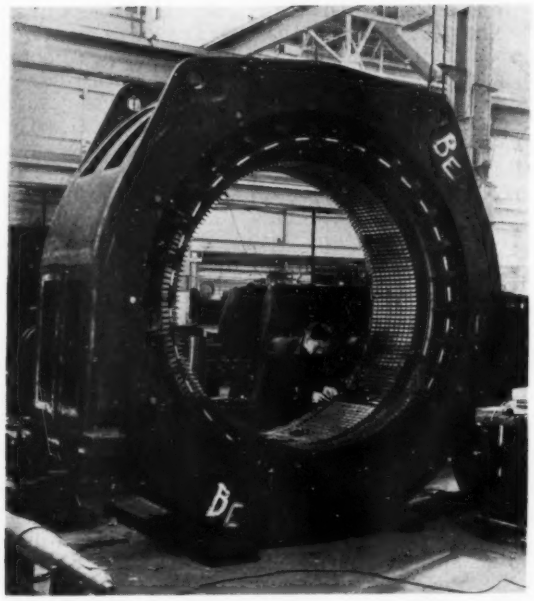
of manufacture for the Shawinigan Engineering Company, Canada.

These units have a voltage ratio of 125/66 kV, and regulation over a range of plus and minus 12 per cent. in 20 equal steps is provided on the high voltage side by means of on-load tap changing equipment. The tap changing equipment is designed for push button control. The two transformers are among the largest to be exported from Great Britain.

Harland Engineering Company, Scotland. — The agreement to manufacture water turbines of all types under licence from S. Morgan Smith Co. of York, Pennsylvania, permits Harland to draw upon the wealth of knowledge of the American company which has produced water turbines totalling more than 11,000,000 h.p. To this Harland add their own already wide experience of hydraulic and electrical engineering, and the resources of a large and modern works. Harland's enterprise has resulted in the award of a number of major contracts including the following for the North of Scotland Hydro-Electric Board:—

Power Station	No.	Water Turbines			Alternators	
		Type	H.P. Each	Gross Head	kW Each	Volts
				Feet		
Grudie Bridge	2	Vertical Francis	17,500	560	*12,000	11,000
Glascarnoch	2	,,	17,500	526	*12,000	11,000
Loch Striven	2	Horizontal Francis	4,375	404	3,000	3,300
Allt-na-Lairige	1	Horizontal Impulse	8,850	780	6,000	11,000
Storr Lochs	2	Horizontal Francis	†1,150	447	80	3,300

*Alternators by Bruce Peebles & Co.
†Turbines by Gilbert Gilkes & Gordon Ltd.



Winding a Harland water turbine-driven alternator stator

Among the export orders secured is one from Messrs. Ewbank & Partners Ltd. for the Jamaica Public Services Co. for a vertical shaft Francis turbine of 5,600 h.p. coupled to a 4,000 kW, 6,900 volt, synchronous generator.

John M. Henderson and Co., Aberdeen. — Early in 1948 the company put into operation for the North of Scotland Hydro-Electric Board two electrically-driven radial cableways for the construction of the dam at Loch Sloy. Each of these plants is 1,350 ft. span and capable of lifting loads of 10 tons. Two similar cableways of 1,800 ft. span are in course of construction for the Glen Shira scheme. One of the largest contracts they have ever carried out for hydro-electric schemes is just approaching completion in Portugal.

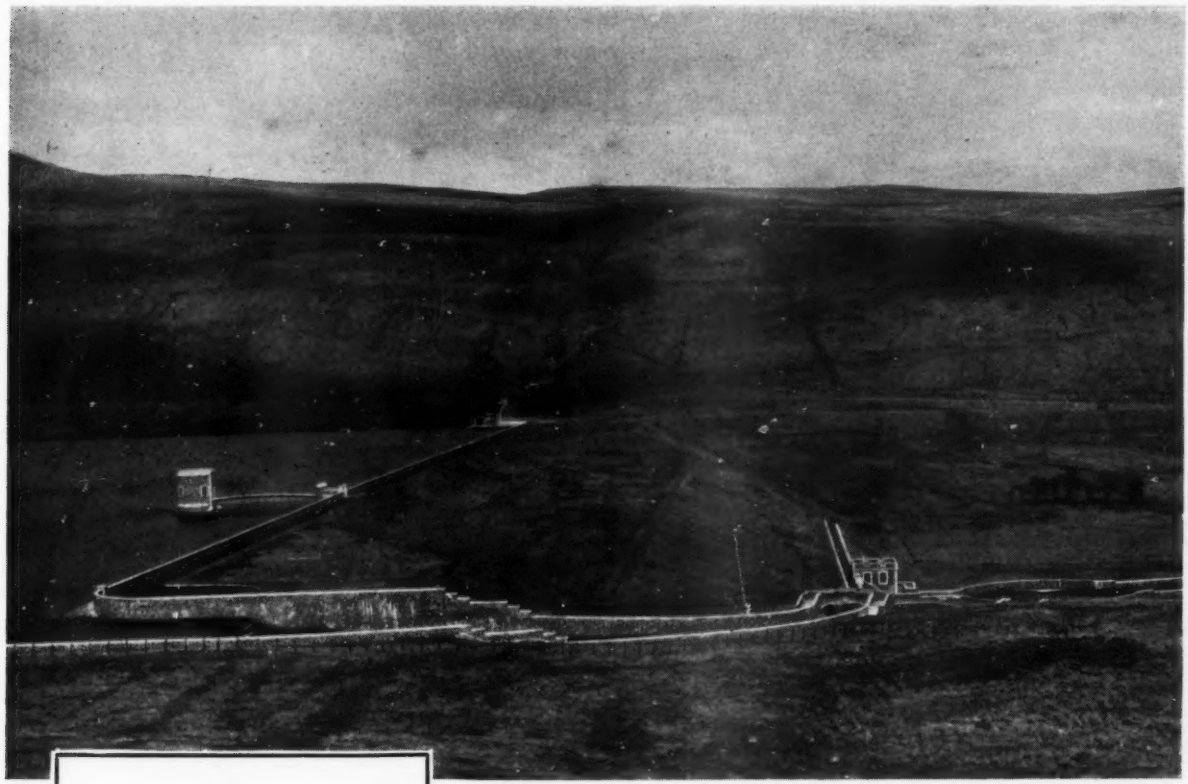
Science in Industry

A full report is now available of the proceedings at the British Thomson-Houston summer school in electrical engineering, which was held at the Rugby works last year.

Among those attending the lectures were professors or their senior colleagues from virtually all the electrical engineering faculties of Great Britain, including Service colleges, together with representatives of those great establishments for service and education—the National Physical Laboratory, the Department of Scientific and Industrial Research, and the Institution of Electrical Engineers.

Sir John Cockcroft, director of the Atomic Energy Research Establishment at Harwell, in an opening address which emphasized the needs of the laboratories and industry of the country for scientific and technical staff, recommended a substantial increase in post-graduate study in engineering, and an even larger increase in the scale of financial assistance.

Whatever and wherever the project



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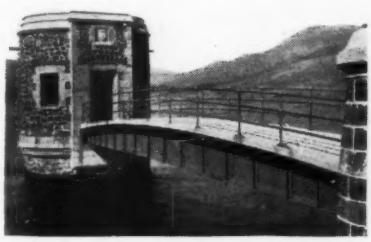

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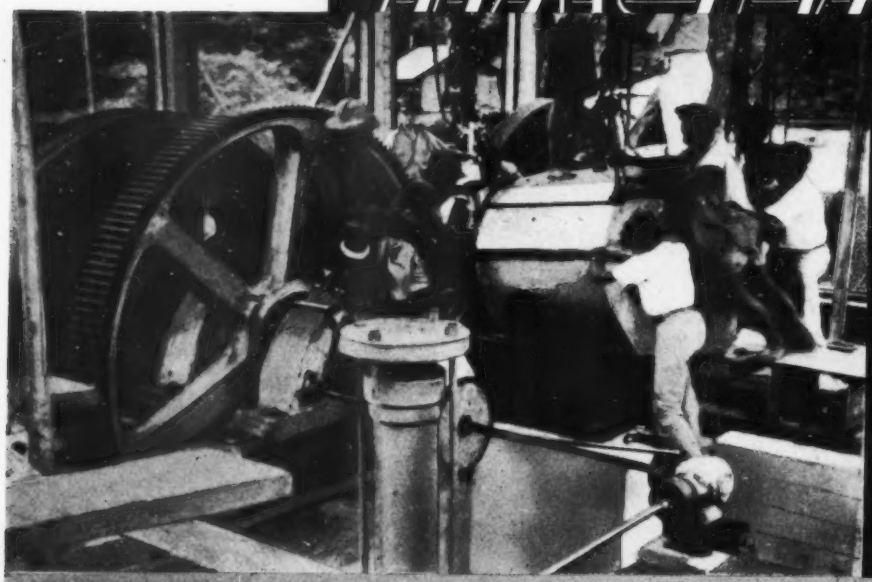

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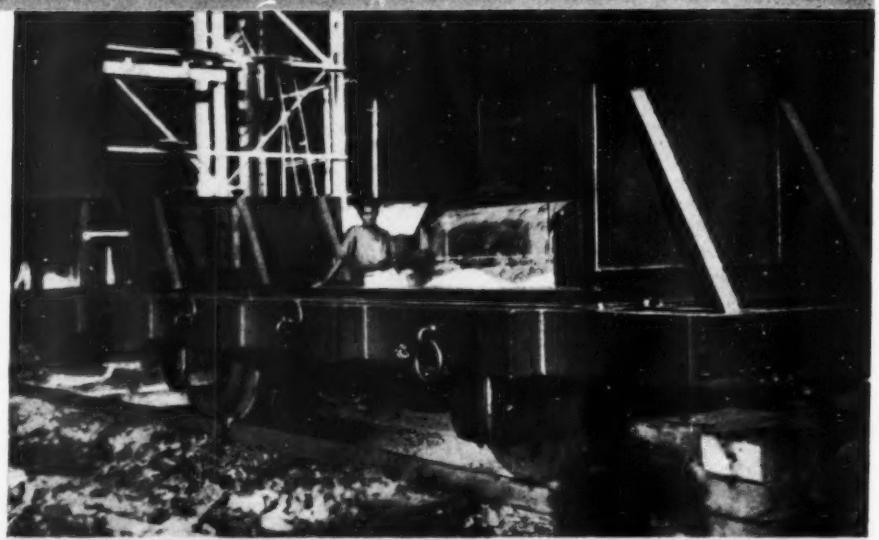

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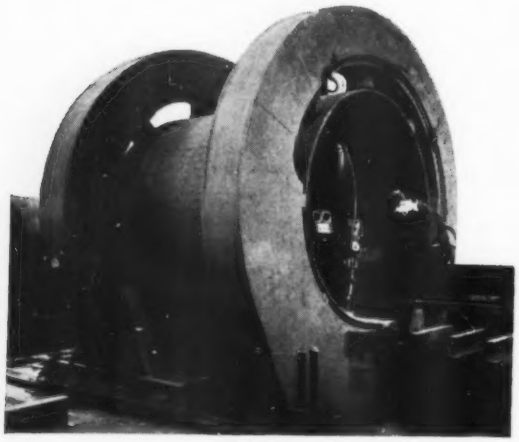

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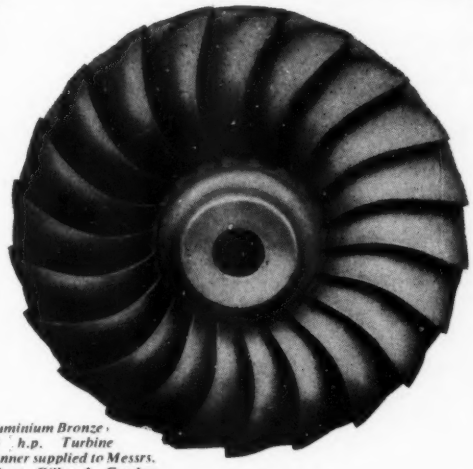

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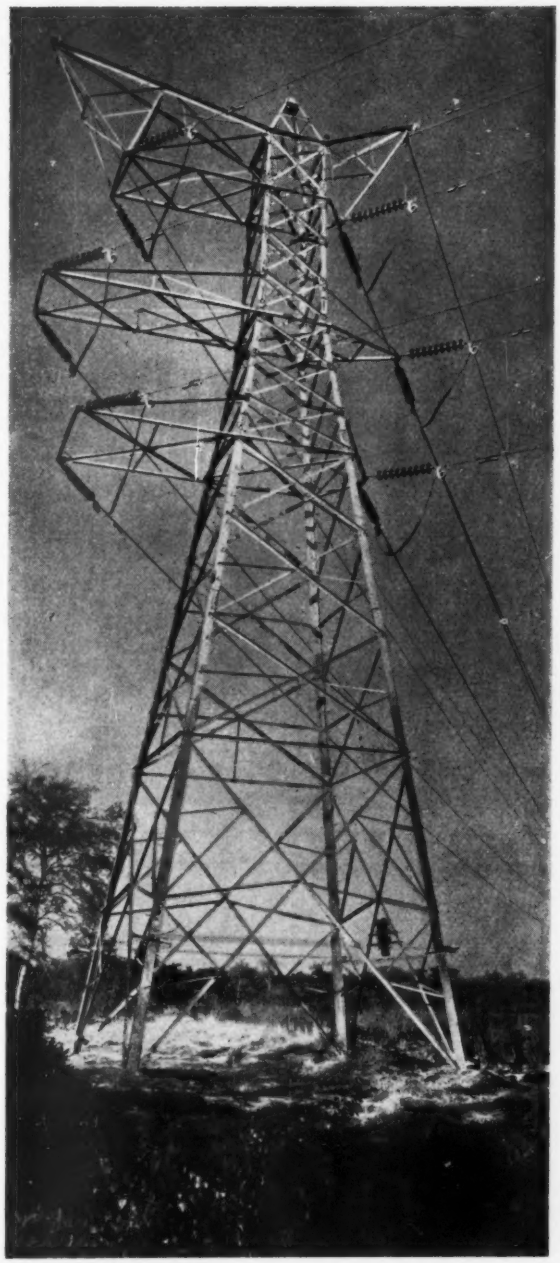

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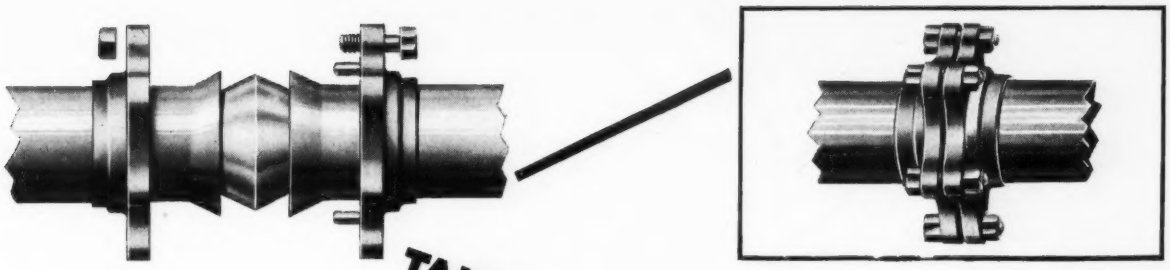

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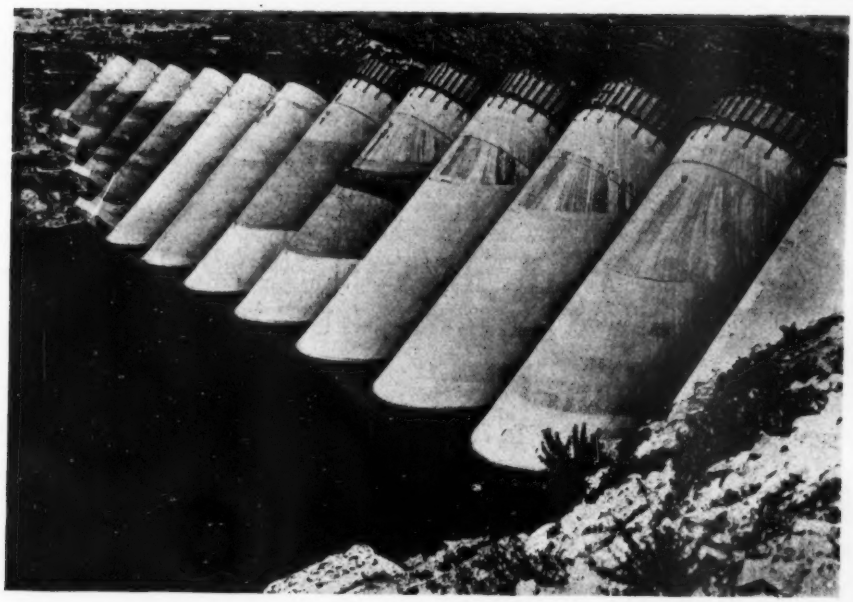

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INDEX TO ADVERTISEMENTS

A
Atlas Diesel, Aktiebolaget 19

B
Balfour, Beatty & Co. Ltd. ... 38
Birkett, T. M. & Sons Ltd. 39
Blackwood, Hodge J. & Co. Ltd. ... 29
Blakeborough, J. & Sons Ltd. ... 10
Boving & Co. Ltd. 7
Brady, G. & Co. Ltd. 24
British Insulated Callenders Cables Ltd. 34
British Thomson-Houston Co. Ltd. 23
Brown Boveri & Co. Ltd. 5
Butters Bros. & Co. Ltd. 16

C
Cementation Co. Ltd., The 42
Consolidated Pneumatic Tool Co. Ltd. 25
Costain, Richard Ltd. 31

E
Ellison, George Ltd. 12
Enfield Cables Ltd. 22
English Electric Co. Ltd., The *Front Cover* and 11

F
Firth-Vickers Stainless Steels Ltd. ... 37
Fusarc Ltd. 38

G
Gilbert Gilkes & Gordon Ltd. ... 17
Glenfield & Kennedy Ltd. 3

H
Hackbridge & Hewittic Electric Co. Ltd. 6
Harland Engineering Co. Ltd., The 32
Henderson, John M. & Co. Ltd. ... 14

I
Ingersoll Rand & Co. Ltd. ... 30

K
Karlstads Aktiebolaget Mekaniska Werkstad 21

L
Lamont, J. H. & Co. Ltd. 41

M
MacLellan, Geo. & Co. Ltd. ... 40
Marine Instruments Ltd. 4
Metropolitan-Vickers Electrical Co. Ltd. ... ... *Back Cover*
Millars Machinery Co. Ltd. ... 26
Mitchell Bearings 38

N
Newport News Shipbuilding & Dry Dock Co. 9

P
Poles Ltd. ... *Inside Back Cover*
Pyrontenax Ltd. 28

R
Reyrolle, A. & Co. Ltd. *Inside Front Cover*

S
Sika Ltd. 41
South Durham Steel & Iron Co. Ltd. 13
Steatite & Porcelain Products Ltd. 8

T
Taylor Woodrow Construction Ltd. 27
Teeside Bridge & Engineering Works Ltd., The 39

W
Whatlings Ltd. 20
Wimpey, Geo. & Co. Ltd. ... 35
Winget Ltd. 18
Wild, M. B. & Co. Ltd. 36

Y
Yorkshire Electric Transformer Co. Ltd. 15

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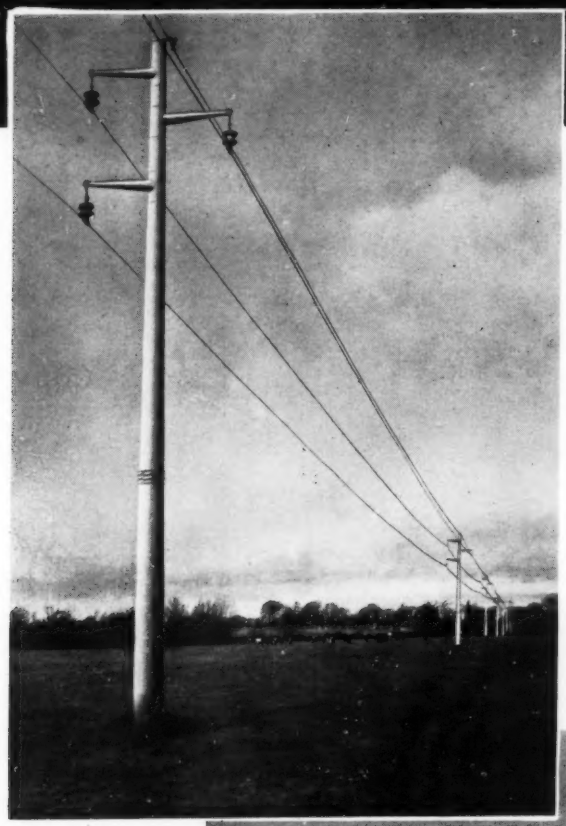

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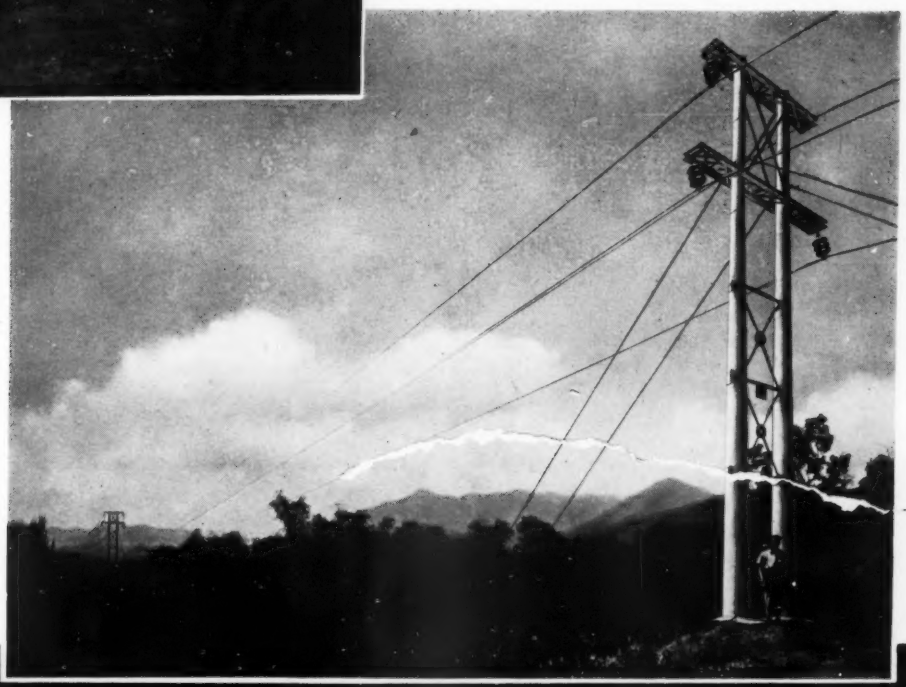

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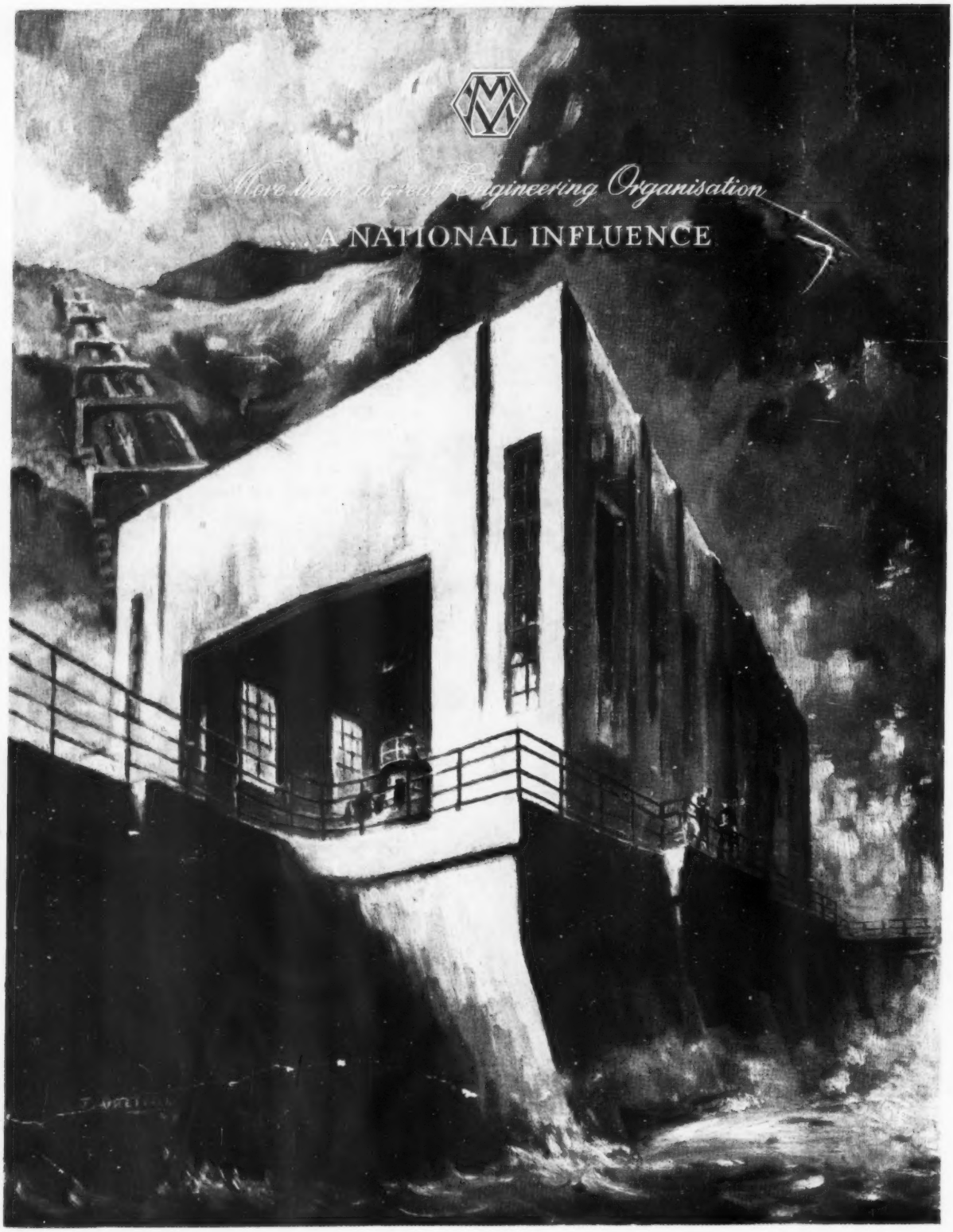

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